



THE BRATSK-ILIMSK TERRITORIAL PRODUCTION COMPLEX

**PROCEEDINGS OF THE SECOND IIASA
CONFERENCE ON CASE STUDIES OF LARGE-
SCALE PLANNING PROJECTS
MARCH 22-25, 1976**

HANS KNOP, Editor

**CP-77-3
JUNE 1977**

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Views expressed herein are those of the contributors and not necessarily those of the International Institute for Applied Systems Analysis.

The Institute assumes full responsibility for minor editorial changes, and trusts that these modifications have not abused the sense of the writers' ideas.

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PREFACE

This volume represents the second in a series of IIASA conference proceedings dealing with case studies of large-scale regional development programs. The Tennessee Valley Authority in the United States was the subject of the first Conference, and the presentations on methods and activities pursued appear in the proceedings.*

The second case study, the Bratsk-Ilimsk Territorial Production Complex (BITPC), is an example of how large-scale regional development programs are integrated into the system of national economic planning in the Soviet Union. The BITPC is the first of the major territorial production complexes in the Soviet Union, and the experience gained there is being used for the development of similar programs. Countries with similar development objectives will find it useful to examine the experience of Soviet scientists and practitioners. IIASA is indebted to the United Nations Environment Programme for its partial support of this work.

These Proceedings cover only the initial stage of IIASA's study of the Bratsk-Ilimsk Complex. The presentations included were prepared by the Soviet scientists actively involved in developing the concept of TPCs. IIASA scientists prepared additional papers, based on the presentations, in order to stimulate discussion and to clarify some of the issues raised. The presentations and the discussions served as the basis for a more detailed field study of the Bratsk-Ilimsk Complex and the general role of TPCs in the Soviet Union carried out by IIASA scientists in mid-1976. A report of this field study will be published by IIASA in late 1977.

The BITPC case study provides an excellent framework for discussing the effective management of large-scale regional development. It is a pleasure to thank the State Committee for the USSR Council of Ministers for Science and Technology, and the Soviet scientists who prepared papers for the Conference. Their work has deepened our knowledge in this area and will be of interest to all decision-makers dealing with similar problems.

*Hans Knop, Editor, *The Tennessee Valley Authority*, 2 Vols., CP-76-2, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1976.

Finally, I wish to express my appreciation to the IIASA staff, in particular, Brunhilde Buerger, Anna John, and Eryl Ley for their dedication and hard work at the Conference. Special thanks are also due to my able assistant, Robert Tuch, who played a major role in assembling the Conference material and in finalizing these Proceedings. I also wish to extend my thanks to the editorial staff for producing what I consider an excellent publication: to Jeanne Anderer who technically edited these Proceedings, and to Barbara Lewis and Angela Marsland who helped produce the final copy.

Hans Knop
June 1977

Table of Contents

<i>Welcoming Address</i> R.E. Levien	1
---	---

INTRODUCTION TO THE BITPC

<i>Introduction</i> G. Aleksenko	5
<i>The Role of the Bratsk-Ilmsk Complex in Developing the Productive Forces of Siberia</i> A. Aganbegyan	7
<i>Large-Scale Planning Projects: Applied Systems Analysis in Regional Programs</i> H. Knop	15
<i>Long-Term Planning in the USSR and Decisionmaking for the Development of the BITPC</i> L.I. Gramoteyeva	23
<i>The Contribution of the BITPC to Solving Long-Term Development Problems of the Angara-Yenisei Region</i> V.A. Shelest	35
<i>Experience in the Formation of the BITPC</i> V.P. Gukov and A.N. Semyonov	43
Discussion	61

PLANNING, MANAGEMENT, AND ORGANIZATION

<i>The Role of Republic and Local Planning and Management Bodies in the Development of the BITPC</i> N.A. Soloviev and K.Ya. Donchenko	65
<i>Prospective Links Between the BITPC and the Region of the Northern Part of East Siberia</i> G.L. Tarasov	73
<i>Analysis of Regional Strategy Setting</i> D.v. Winterfeldt	83

<i>Management of the BITPC</i> V.P. Gukov and N.G. Perevalov	95
<i>An Organizational Approach to the BITPC</i> C. Davies, A. Demb, and R. Espejo	111
<i>Implementation of a Long-Term Program for the Development of the BITPC</i> G.M. Filshin	121
<i>Planning and Management of the Investment And Construction Process</i> K.H. Schaffir	131
<i>Summary Report on the Technical Session on Planning, Management, and Organization of the BITPC</i> H. Knop	139
Discussion	140

ENERGY SYSTEMS AND WATER RESOURCE PROBLEMS

<i>Introduction</i> A.A. Makarov	145
<i>Mathematical Models for Optimizing the Development of Integrated Electric Power Systems in Siberia</i> L.S. Belyaev, A.A. Papin, and A.N. Zeiliger	149
<i>Indirect Expense Accounting in Planning Siberian Fuel-Power Resource Development</i> Yu. D. Kononov	161
<i>Physical and Mathematical Simulation for Solving Problems of Power System Functioning</i> Yu.M. Gorsky and Yu.S. Konovalov	167
<i>Energy Accounting</i> F. Niehaus	179
<i>The Role of the Bratsk and the Ust-Ilimsk Hydropower Stations in the Joint Siberian Power System</i> A.P. Kurbatov and L.E. Khalyapin	187
<i>Angara-Yenisei Hydroelectric Power Station Cascade</i> A.Sh. Reznikovskiy	193
<i>Water Resource Systems</i> Z. Kaczmarek	199

<i>Runoff Regulation of the Angara-Yenisei Cascade Hydropower Stations</i> L.S. Belyaev, V.A. Saveliev, and L.E. Khalyapin	201
<i>Summary Report on the Technical Session on Energy Systems</i> A.A. Makarov	211
<i>Summary Report on the Technical Session on Water Resources</i> Z. Kaczmarek	213
Discussion	215

DEMOGRAPHIC AND SETTLEMENT PROBLEMS

<i>Population and Manpower Resources in the BITPC</i> V.V. Vorobyov, L.K. Zmanovskikh, and G.M. Podlinyaev	219
<i>Dynamics, Prognosis, and Planning of Population Changes in the Bratsk-Ilimsk Area</i> A. Rogers	227
<i>Development Patterns of Linear-Node Structures of Territorial-Production Complexes in Developing Areas</i> K.P. Kosmachev	237
<i>Systems Approach and Mathematical Models For Integrative Planning of the Development of a New Industrial Region</i> J.R. Miron	249
<i>The Use of Graph Theory in Regional Development</i> H.P. Young	251
<i>Medical-Geographic Problems in the Formation of Territorial-Production Complexes in Siberia</i> B.B. Prokhorov	253
<i>Integrative Elements of Regional Development</i> W.A. Welsh	263
<i>Summary Report on the Technical Session On Demographic and Medical Problems</i> A. Kiselev	273

MODELING REGIONAL DEVELOPMENT

<i>Modeling of Territorial-Production Systems: Case Study of the Angara-Yenisei Region</i> A.G. Granberg and M.K. Bandman	277
--	-----

<i>Optimization of a Long-Term Program for the Formation of a Territorial-Production Complex</i> A.M. Alekseev and L.A. Koslov	301
<i>Optimum Use and Conservation of Forest Resources of the BITPC</i> I.N. Voevoda, A.N. Teplov, and M.A. Sokov	311
<i>Systems Approach and Mathematical Models for Integrated Regional Development Planning</i> A. Straszak	321
<i>Models for Regional Development Planning</i> J. Owsinski	325
<i>A Simplified Framework for the Use of Models in Planning</i> Wm. Orchard-Hays	337
Discussion	341

CLOSING SESSION

Closing Remarks	345
H. Knop	
G. Aleksenko	
H. Mottek	
S. Komorovski	
E. Schulz	
R. Tomlinson	
M.I. Foster	
Y. Iwasa	
R.E. Levien	
J. Gvishiani	

APPENDIXES

Appendix 1: Information on Economic Planning and Management Systems in the USSR	359
Appendix 2: Participants and Authors of Conference Presentations	365

Welcoming Address

R.E. Levien

I would like to welcome you to the second IIASA conference on large-scale planning projects which focuses on the Bratsk-Ilimsk Development Project in the Soviet Union. The first conference, held in October 1974, focused on the Tennessee Valley Authority in the USA.

I think it is appropriate to say a few words about the Institute and how this Conference fits into our evolving research strategy. IIASA was founded in 1972 to bring together scientists from around the world--in the beginning from East and West, but increasingly from developing countries as well--to work on problems shared by their nations. These problems are both *global*--those whose impact and resolution involve groups of countries--and *universal*--those which each nation faces within its borders.

IIASA's approach to these problems is interdisciplinary, recognizing that in their complexity the problems we choose to work on demand a more comprehensive approach than can be applied in a single disciplinary atmosphere. In addition to its own research, IIASA aspires to build networks of institutions with coordinated research programs, and to facilitate the exchange of experience among countries.

To accomplish its objectives, the Institute requires both a broad base of competence in many disciplines and topic-oriented studies that draw this expertise together in policy analysis. These requirements lead us to IIASA's research structure and direction. As the base of competence for the Institute's work we have four Research Areas: *Resources and Environment*, dealing with the earth's natural endowment; *Human Settlements and Services*, dealing with the earth's human endowment; *Management and Technology*, concerned with man-made contributions to the global endowment; and *System and Decision Sciences*, dealing with the mathematical and computational tools for systems analysis within an area and for studies which cut across areas.

IIASA has the opportunity to draw upon the body of knowledge and expertise within these areas to perform substantive, objective analysis of global and universal problems. At the *global level*, we are concerned in the long term with the pace and direction of global development. But before we can tackle such an awesome task, we have chosen first to look systematically at the development of individual sectors: energy and food, for example, and their linkages with other sectors. IIASA now has one crosscutting

global program on global energy systems, and is contemplating another on food and agriculture.

At the *universal level*, we have a different problem. Whereas sectorial models are often well developed, methods and approaches that link them together are lacking. IIASA has chosen to look at these linkages: integrating concepts and approaches for dealing with the development of geographic regions. Our crosscutting program is Integrated Regional Development.

Within this framework, this Conference on the development of the Bratsk-Ilimsk region assumes great importance for IIASA. We will approach Bratsk-Ilimsk from a multidisciplinary perspective, with each of our Research Areas participating in the Conference. We want to examine approaches and methodologies that have been used in Bratsk-Ilimsk and to draw lessons for the future: lessons that will help the scientists decide what research to pursue and the policymaker to decide which aspects of the Bratsk experience might be applied to other development projects. We hope that the Bratsk-Ilimsk experience will stimulate discussion and exchange of insight among scientists and between scientists and policymakers.

IIASA is particularly grateful to Academician Aganbegyan who has coordinated the Soviet documentation and presentations on Bratsk. He has worked closely with Professor Knop, leader of IIASA's Management and Technology Area, who has played a major coordinating role in the organization of the TVA and the Bratsk-Ilimsk studies.

INTRODUCTION TO THE BITPC

Introduction

G. Aleksenko

This Conference is an excellent opportunity to examine the experience of the planned development of a socialist system of economy that provides for a purposeful, comprehensive, and effective use of resources and capital investments for society. In the USSR, large-scale and long-term national and regional programs are an important instrument for development. During the early period of the Soviet state, Lenin initiated and supervised the integrated program of electrification of the country--the Goelro Plan--which helped to create the material and technical foundation for the socialist system. Since then, other major programs have been successfully implemented such as the creation in the 1940s of a coal and metallurgical base in the Eastern part of the country, the development of the Northern territories, and the development of large regions in the Central Asian and Far Eastern part of the USSR. These programs combine sectorial and territorial development, taking into account the interrelation of economic, technical, social, political, demographic, ecological, and geographical factors. To achieve these goals, a systems approach to planning, designing, and managing large-scale programs is essential.

The recent 25th Congress of the Soviet Communist Party (CSCP) devoted special attention to formulating and implementing comprehensive programs for developing large regions of the country.

In reporting to the Congress, the General Secretary of the Central Committee of the CSCP, Leonid I. Brezhnev, stressed that there should be more rational and purposeful allocation of the country's productive forces to meet the development needs of new areas, in particular, those areas rich in raw materials and fuels.

In accordance with the decisions of the 25th Congress and the Soviet Government, large-scale work is being done on creating integrated programs for developing natural and economic resources of many regions of the Soviet Union--e.g., the non-black soil zone, the West Siberian and Sayan Complexes, and Irkutskia; the further development of the Bratsk-Ilimsk Territorial Production Complex (BITPC).

We have the requisites for such development: public ownership of the means of production, a planned system of economy, and the productive, scientific and technological potential. Using the example of the BITPC, the scientists and specialists who are members of the Soviet delegation to this Conference will show how

these requisites have been used for the many regional development programs.

We are convinced that the BITPC is interesting for several reasons. First, it plays an important role in the industrial development and electrification of Siberia by implementing a series of long-term programs for developing the region's productive forces. It covers a vast and undeveloped region whose population has increased tenfold since the creation of the complex about 25 years ago. The complex is truly multisectorial and multifaceted: it includes large hydropower stations such as the Bratsk and the Ust-Ilimsk stations, many enterprises of various nature, and several new towns such as Bratsk, Ust-Ilimsk, Shelesnogorsk, and Ust-Kut. The main projects of the complex have been developed in record time with a clearly defined and interrelated plan. Its overall development is viewed as an integral part of an even larger program--that of developing the natural resources of the Angara-Yenisei Region. Scientific projections and feasibility studies played an important part in the construction of the complex. For example, considerable research was done on the use of regional economic mathematical methods for identifying optimal solutions.

We think the main aim of this Conference is to acquaint the participants and representatives of various countries with the organizational forms and methods used for implementing the BITPC regional development program. The experiences discussed here reflect the peculiarities of our system as a whole and the conditions of this specific region in our country. It is our belief that the study of the Soviet model for creating a regional complex in the form that it now exists and develops is very fruitful and will contribute to IIASA's work.

The Role of the Bratsk-Ilimsk Complex in Developing
The Productive Forces of Siberia

A. Aganbegyan

Because of the great variety of regions in the USSR, we are faced with the difficult task of selecting an example of a territorial organization for production and living that typifies the efforts being made in the Soviet Union for the planning and management of large-scale development programs. I was fortunate to have participated in the IIASA case study development of the Tennessee Valley in the United States, and to draw much from that experience.

Why have we chosen the Bratsk-Ilimsk Territorial Production Complex (BITPC) as the theme for this Conference? There are many development programs in the Soviet Union that are larger in scope than the BITPC--programs that cover large economic areas and entire regions such as Western Siberia and the Angara-Yenisei Region. The BITPC, as an integral part of the Angara-Yenisei Region, was selected because it illustrates how the territorial production complex (TPC) works to ensure the rational development and use of a region's natural resources.

Currently in the USSR, there are about 100 TPCs that are either operational or in the development stage. The BITPC is a typical example; therefore its main procedures, organizational forms, operational system of planning and management as well as the the BITPC experience in formulating and realizing its program are applicable to other TPCs.

The BITPC is part of an overall large-scale regional development program; to understand the BITPC, it is necessary to understand the larger program--how it is being carried out and also how it is linked with lower regional bodies such as industrial units and small districts.

The BITPC covers three administrative districts. It is part of the Irkutsk administrative region within the West Siberian economic region that is a part of the Russian Federation. The administrative regions are further divided into districts: the BITPC covers three of the districts in the Irkutsk administrative region. The middle position of the BITPC was one of the reasons for selecting it as the subject of this Conference. The TPCs take a middle position in the hierarchy of territorial and national economic objectives of planning and management. The TPCs may be considered an efficient means for the structural organization of solutions to the problems of coordinating the

interests of the national economy, industrial and regional development in the USSR.

Another major reason for selecting the BITPC is the unique conditions under which it has developed. Climatic conditions in this area are severe--extremes of cold in the winter, and heat in the summer and work of any kind is difficult. These conditions, however, are typical of many regions now being developed in the USSR.

Unique Siberian conditions--e.g., vast territories, a unique assortment of natural resources, severe climatic conditions, and labor shortages--require unique planning and management activities. The TPCs in Siberia not only contribute to the development of the economy as a whole, but also are an economically forceful means for overcoming specific Siberian conditions.

While the BITPC has many characteristics in common with other TPCs, it also has a number of distinguishing properties. The BITPC is a powerful unit that greatly influences the development of social production in the entire USSR, particularly in Siberia. Productive forces were developed in Bratsk not only to meet the needs of the small population in the BITPC region, but also to provide electricity and other energy forms for the areas of Siberia and to furnish essential products for domestic and overseas purposes.

CHARACTERISTICS OF THE BITPC

The development program of the area that is now encompassed by the BITPC began more than twenty years ago (1954-1955). In this relatively short period there have been major industrial and social accomplishments. Two large hydroelectric power stations of tremendous capacity have been built. The volume of the reservoirs created after the closure of the dams is 50 km³. The extensive forest resources of the region are efficiently used by timber complexes such as Bratsk which produces about 20 million m³ of sawn timber and over one million tons of cellulose. Another cellulose plant is being built in Ust-Ilimsk which will produce 624,000 tons of cellulose per year. The wood processing and cellulose complexes make the BITPC one of the largest cellulose and timber producing regions in the USSR.

In addition to the hydroelectric and timber processing facilities, a large aluminum plant has been constructed which produces large quantities of high grade aluminum products. Iron-ore mining and processing facilities are also contained within the BITPC, the annual figure of enriched iron-ore production is 6.5 million tons.

All the facilities were built on a rather small territory compared to other territories of the USSR. Thus it was necessary to create a large construction organization that could provide

the skills and organizational base needed for integrating the development of the Bratsk-Ilmsk region. Bratsk gesstroï was created to construct individual enterprises and to ensure that the necessary infrastructure of transportation, communication, and social facilities would be available.

The concept of unified construction characterizes the efficiency of the BITPC within the Soviet Union. It is one of the country's most effective territorial industrial complexes. Electricity is produced by the Bratsk Power Station at a cost of only 0.035 Kopeks/kW; the great forests along the Angara are harvested and processed practically without waste. The efficiency of these and other enterprises reflects the importance of a single large construction organization that is flexible in distributing its forces, and can perform major construction work on a simultaneous basis. It was only five years between the time that the first construction workers came to Bratsk and the first cubic meter of rock was extracted, and the time when the power units were commissioned. The Soviet Union has never experienced such a fast rate of construction for a project of this scale.

At this Conference many papers will be presented and discussed about different aspects of the BITPC. I would therefore like to speak about the territorial organization of our national economy.

The national economy of the USSR is characterized by its planned nature, with key emphasis placed on a central plan. Figure 1 presents a simplification of the forecasting and planning system that resulted in the establishment of the BITPC and many other complexes of a similar type.

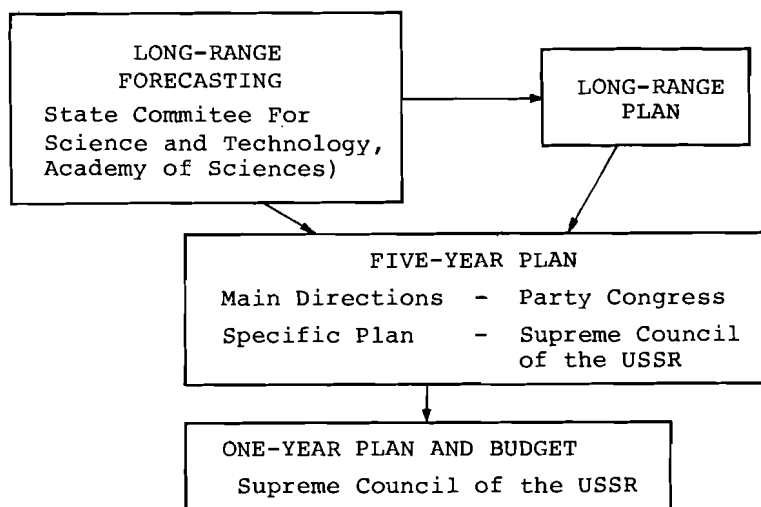


Figure 1. Forecasting and planning system in the USSR.

Before the plan is elaborated, large-scale work is accomplished under the guidance of national bodies that deal with long-term forecasting of the national economic development of the USSR. The overall head of this work is the State Committee for Science and Technology. Professor Alexenko, who leads our delegation to this Conference, is also the head of a commission on long-term forecasts of fuel and energy requirements. Under the guidance of this State Committee, institutions of the Academy of Sciences, ministries, departments, and designated organizations participate in the elaboration of long-term forecasts up to the years 1990 and 2000. These long-term forecasts, which are elaborated for the key branches of the national economy, serve as the basis for scientific, economic, technological, and social work carried out by the State Planning Committee (GOSPLAN). These bodies work together to elaborate the long-term plans for the next 15 years. This work is not completed, and the recent Party Congress has requested that this work be completed over the next few years. Currently, we have no integrated plan covering the next 15 to 20 years. The problems of developing the productive forces for this period are being worked on by special governmental decrees, which will be adopted after preliminary work has been completed.

The basis form of planning in our country is the five-year plan. We have started to fulfill the 1976-1980 Plan. The basic plan is formulated as follows. Every five years, a Congress of the Soviet Communist Party is convened--the Party is the guiding and leading force in our society; and the Congress approves the basic directions of the plan for development over the subsequent five-year period. These directions are thoroughly studied, and the plan is then approved and adopted by the Supreme Council of the USSR.

Five-year plans are worked out in detail and are broken down into annual plans. The annual plans contain individual indicators of the five-year plans, and are developed and specified on the basis of annual budgets. These annual plans and budgets are also approved by the Party's Central committee, as was the case for the plans for the Bratsk-Ilimsk Complex.

The nineteenth Congress of the Party set forth directives for creating the Bratsk-Ilimsk Complex, and subsequent five-year plans dealt with the specifications and progress of the BITPC. For example, after the Bratsk Hydropower Station had been developed, a decision was taken to build the Ust-Ilimsk station; after the development of the Bratsk Complex, it was decided to construct the Ust-Ilimsk cellulose plant in cooperation with the member countries of the Council for Mutual Economic Assistance (CMEA). The tenth Quinquennium has set forth the task of completing the development of the BITPC.

About twenty-five years have passed since work began on the BITPC. This planned approach to developing the territorial and productive forces is not an easy procedure. Among the most

difficult problems we have faced are how to interrelate the sectorial approach where power engineers are interested in energy, aluminum engineers in aluminum etc., and how to integrate this sectorial approach with a territorial approach. The territory has its own peculiarities; it requires an integrative approach for various sectors such as a uniform transport system, and a unified production infrastructure. All these factors integrate sectors and branches.

What should be done to interrelate the sectorial or departmental approach with the territorial units in order not to violate the territorial unity? How can we combine this complexity with specialization? For the development of a systems approach, it is necessary to use a program-oriented approach.

Programs are being developed to realize large-scale economic goals that go beyond the boundaries of individual sectors and sometimes individual territories. They require integrative efforts, not only within a certain territory or industry, but also on a national scale. This program-oriented approach has been characteristic of our plans, starting with the Goelro Plan which was drawn up under the guidance of Lenin. As a result of the development of systems analysis, this program-oriented approach is becoming more important and more personal and formal procedures are being developed.

All the above elements have been integrated in our five-year plans which do not give a sum of sectorial indicators, but rather are comprehensive and integrative in nature. The five-year plans have sections concerning the development of sectors, and sections pertaining to the allocation of productive sectors. Within the State Planning Committee there is a special division that interrelates the sectorial indicators, adjusts them if necessary, and forms the point of view of the integrated development of a territory.

I am sure that everyone here understands that drawing up a plan to guide the work is preceded by a pre-planning stage which is related to the scientific substantiation of the decisions taken. Let me use Siberia as an example.

There are several stages of scientific preparation or substantiation for the development of a new territory. We have academic organizations and research institutes that work in advance of the elaboration of a five-year plan. They carry on research dealing with key problems of regional development, and prepare scientific reports on these subjects. In addition, multi-purpose ideas are advanced which use techniques such as situation analysis. The Institute of Economy and Organization of Industrial Production, which is located near Novosibirsk in the center of Siberia, deals with problems of developing the productive forces of Siberia using these approaches. Professor Tarasov who is charged with establishing the Institute for the Organization of Far Eastern Development is present at the Conference. These

research papers and scientific reports are used by institutions and organizations in our country for planning activities for the development of new regions. This preliminary work is lead by the Council for Productive Forces attached to the State Planning Committee of the Soviet Union.

The Deputy Director of the Council, Professor Gramoteeva, will report to the Conference on the activities for producing schemes for developing the productive forces of individual regions. These schemes are drawn up through the efforts of large programs in which sectorial organizations take part and which also include territorial organizations directly representing the territories. This material is then sent to the Council for the Study of Productive Forces which works together with the research institutes under Gosplan and with the central economic institutes under the State Planning Committee of the Russian Federation. Through their combined efforts, a preview document is drawn up which is the basis of government decisions on the development of new territories and productive forces.

The scientific substantiation of such a plan involves the use of mathematical methods and models. This work is done under the leadership of the Central Economic Mathematical Institute in Moscow with assistance from our Institute in Siberia. Both Institutes are currently working on a systems approach to modeling using an interrelated complex of models--a system of models. Our current approach is to use the following groups of models: dynamic intersectorial models at the national economic level; intersectorial models dealing with the allocation and distribution of productive forces; optimization, interregional, and intersectorial models dealing with the aggregate hypothesis of regional development; local models of optimal sectorial planning; and models of the comparative development of regions. The sectorial and regional approaches are unified in the program-oriented models.

Many of these types of models will be discussed at this Conference.

Work is now being done on completing the first phase of accumulated plans, systems, and calculations. This is an integrated system which is being developed for the State Planning Committee of the USSR, for the planning bodies of the Republics, and for local planning bodies. This system will help us to improve the quality of our planning activities.

Our development plans do not stop with the completion of the BITPC. The BITPC is the starting point for the development of a vast area--one million square kilometers--that will be the industrial belt of the Soviet Union. The Baikal-Amur Railroad is currently under construction, and will facilitate the industrialization of this part of the country. It is easy to envisage the large-scale development of the productive forces of this region. Bratsk will serve as an example for the further development of the Siberian region.

There are 20 industrial complexes that are in some stage of development, and the BITPC will always be a special case. It is the first complex of this type, and has shown us the value of a comprehensive integrative approach to organizing the productive forces and developing new areas. We plan to continue development along these lines.

Large-Scale Planning Projects: Applied Systems
Analysis in Regional Programs

H. Knop

IIASA ACTIVITIES IN LARGE-SCALE PLANNING PROJECTS

This Conference is the second in a series of IIASA conferences on the experience of large-scale planning projects. This series began in October 1974 with the conference on the Tennessee Valley Authority (USA), followed by a field trip to Tennessee in June 1975 by the IIASA large organizations group. We are pleased to have the opportunity to discuss with our Soviet colleagues the development of the Bratsk-Ilinsk Territorial Production Complex (BITPC); we will follow up this conference with a field study to Bratsk by IIASA scientists in June/July 1976. The next case--to be undertaken in 1977--is the Shinkansen Program, which is a large construction program for the Northern Super Express Railway in Japan.

In addition to conferences and studies, we are analyzing available information on completed and current large-scale planning projects worldwide, for example the Guyana Program in Venezuela, and the Scottish Development Case.

Three other cases, already agreed upon or under negotiation, will involve cooperation with scientific institutes in the respective countries. These are the Lublin Coal Region Development Program in Poland (a working agreement already exists); the Computer-Assisted Regional Management System Project of the Kinki Region in Japan; and the Isfahan Regional Program in Iran (the details of cooperation are being finalized).

In all of these cases we are concerned with the application of systems analysis to regional planning, management, and organization. Since the IIASA large organizations group is small we have to define our role and find appropriate activities.

While these regional development programs differ in many respects, there are some common features--especially in the methodological field. For example, there is the problem of the improved use of resources, with special emphasis on integrating environmental factors in regional planning and modeling. Solutions to this problem should take into account socio-economic and natural conditions; the structure of the methodology for all large-scale planning projects includes the following elements: development concepts and strategies, goals, and objectives; decision analysis and evaluation systems; data base, information,

and model systems; planning algorithms and economic mechanisms; and organization.

SYSTEMS ANALYSIS IN SOCIAL DECISIONMAKING PROCESSES

Complex socio-economic systems are hierarchically structured and have self-stabilizing subsystems. Systems analysis of these systems has much in common with the analysis of natural or technical systems and also differs from it on several counts.

What are the properties of socio-economic systems? These systems--as enterprises, settlements, regions, nations--generally have *multiple objectives* which usually reflect competing and conflicting interests of different social groups and dimensions. In mathematical programming, socio-economic systems are often handled like technical systems: optimization with a given set of constraints and one target function. But this does not adequately reflect reality.

When the planning process begins, many *constraints* are unknown. They depend in part on the assessment of social needs, and in the case of natural resources, on the amount of energy, labor, and capital available for a specific purpose. For example, the availability of a type of ore depends on the existing deposits in a country; at the same time, the amount of ore that is worth extracting economically depends on the possible input of production factors and the degree of use of technologies for refining poor deposits.

The objectives are not completely given and fixed when the planning process starts. The determination of the objectives and the priority given to them is usually a result of the planning process. It is possible to determine objectives only when one knows their requirements and consequences, i.e., the goal-setting process can be effective only when it is an iterative process with a multiplicity of changing parameters.

Only some of the information characterizing a socio-economic system can be quantified since not all social decisions are well structured. The existence of a limited share of quantified information and well structured decisions underscores the need for an iterative approach to socio-economic decisionmaking and limits the opportunities for the use of deterministic models.

Another important characteristic of socio-economic systems is the influence that concerned individuals and groups have on the way the systems act. Each individual has an understanding and evaluation of the system in which he operates and relates this to his interests. All human beings belonging to a socio-economic system act within a certain *organizational framework* which reflects social and political hierarchies, subdivisions of labor and allocations of facilities. All this greatly influences the decision processes and the operation of the system. In a

technical system, there is change in the target function or in the constraints as a result of change in the parameters of the system and in the output. However, because of the human factor, this does not take place in a socio-economic system.

Another characteristic feature of socio-economic systems is the limited possibility for conducting experiments. We consider case studies as one way of overcoming this limitation. The BITPC and existing TPCs have provided the Soviets with valuable information that is being considered in the planning of new TPCs.

We may conclude that complex socio-economic systems do not possess a clearly defined optimum. They are constantly changing as a result of changing internal and external conditions (disturbances) and in fulfillment of a set of hierarchically structured goals and objectives, which in turn change over time. This means that socio-economic systems have to be managed as systems in a state of dynamic adaptability, as learning systems composed of self-adapting and learning subsystems. These subsystems are connected to each other by coordinated relations and to systems of a higher or lower level by subordinated relations. Sometimes this property of systems is called "resilience". Heuristic methods are important for handling these types of systems.

We believe that the application of systems analysis to socio-economic systems needs the cooperation of hard and soft science, and the permanent interaction of modelers, decision analysts, economists, social scientists and decision makers. The social decision process should be regarded as a hierarchical, iterative, and complex human activity.

The background for the social decision process is the *opportunity of choice* in the development of socio-economic systems. This is determined by such factors as needs and goals, paths of growth, external conditions, technologies, siting, timing, socio-economic solutions, and use of resources. The analysis of these factors results in the understanding of the framework in which decisions can be taken and systems strategies can be formulated. These opportunities of choice indicate the variables to be considered in the planning process, which are more numerous than the variables of usual economic, mathematical models.

We can draw some conclusions about the functions of systems analysis in social decisionmaking processes. These functions, which are closely related to the components of social processes, are as follows:

- To understand the complexity of socio-economic systems;
- To determine and reconcile conflicting objectives;
- To arrive at alternative strategies (models, variants) based on the analysis of opportunities of choice;

- To guarantee the consistency of these strategies in a qualitative and quantitative sense, in physical and financial terms, internally and externally, and from the static and dynamic points of view, that is, taking time dependencies and sequences into account;
- To define and find partial or sub-optima;
- To determine a stable/resilient state/path of growth; and
- To formalize the decisionmaking process.

REGIONAL MANAGEMENT ACTIVITIES

We shall focus our attention on managerial activities in and around the BITPC.

By regional management, we mean the planning of a region and its operational management. Both of the activities related to a certain region are performed at various levels and by many governmental and economic management units.

Our studies follow the various lines of *managerial activities*. With regard to the BITPC we will deal with the following managerial functions: permanent analysis of the status and trends of regional development; data management; design and use of the system of data, normatives, balances and models used for forecasting, coordination, etc.; forecast and planning of the region; implementation of the regional plans, monitoring, execution; and regional organization as a third dimension (not shown in Figure 1).

The framework of all the development documents is the system of data, normatives, balances, and mathematical models used for the elaboration of the concepts and plans for a region. Figure 2 shows the principle structure of this system, which was developed over the last 20 years in several countries. The main emphasis is on the type of balances and models used. A scheme related to the stages and functions of planning would be different from that shown.

The system of balances is still the major instrument of regional planning. Besides this, linear mathematical models are used to an increasing extent.

I have given some information about IIASA's approach and some basic concepts of our studies on large-scale planning projects in order to provide background for the discussions of the BITPC.

SUGGESTIONS FOR DISCUSSION OF THE BITPC

At the TVA Conference, the discussion papers prepared in advance by the IIASA scientists proved to be very helpful in

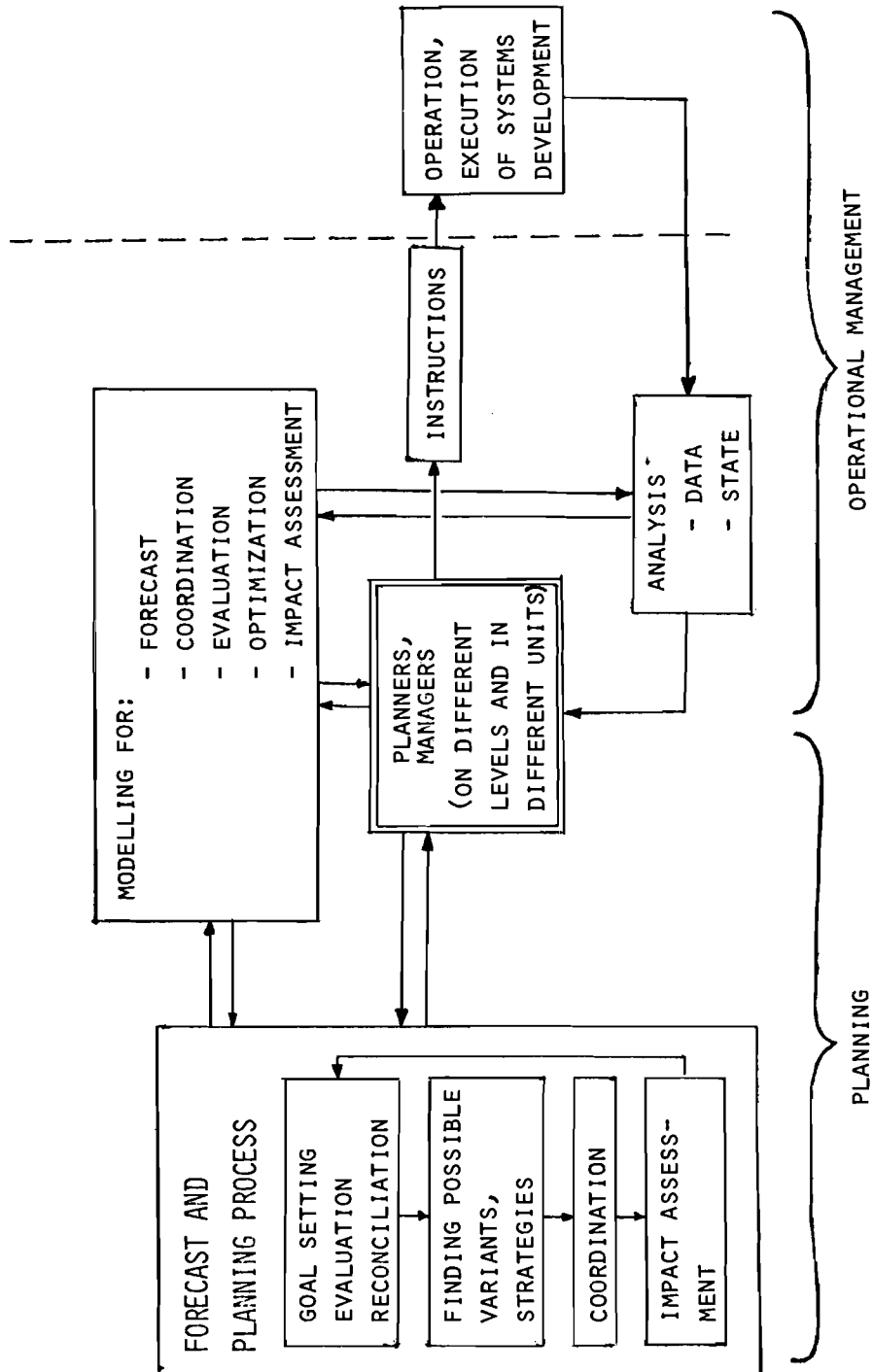


Figure 1. Managerial activities.

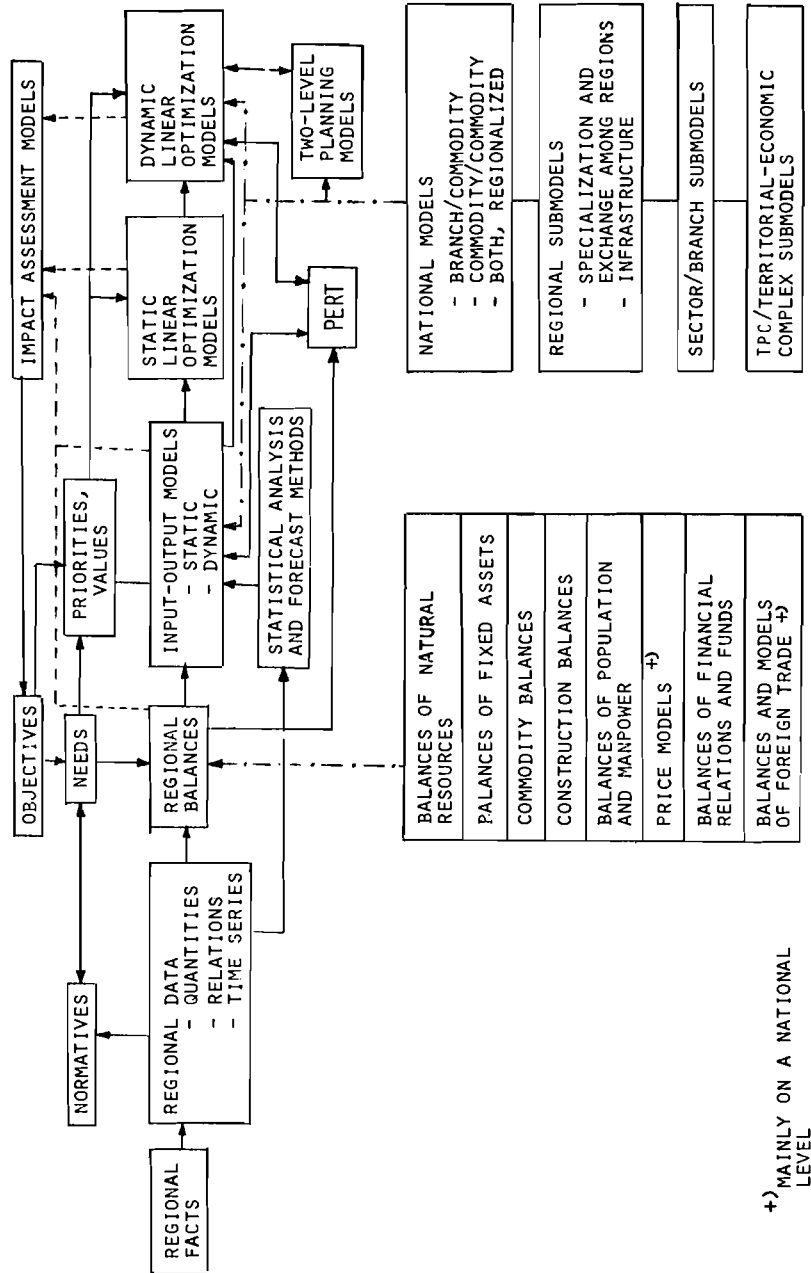


Figure 2. System of data, normatives, balances and mathematical models.

creating a dialogue. Hence, at this Conference we have prepared papers in order to:

- Provide information about IIASA's work on the TVA and other cases;
- Make suggestions from IIASA's viewpoint for structuring the discussion;
- Show our understanding of the concept of the BITPC and its functioning, and likewise receive additional information; and
- Establish guidelines for the field study to the Bratsk Region, to be carried out by IIASA scientists in June/July of this year.

The Soviet papers have presented very valuable scientific and technical information that has created the desire to obtain greater insight into the experiences gained.

Before we go into such details in the sessions that follow, I want to make some general remarks about the concept and strategies for the BITPC.

One of the main characteristics of the program of the BITPC is that it has always been an integral part of the long-range considerations for the overall development of the entire Soviet Union. In this context the Long-Term Plan of the USSR for 1976-1990 and the Master Scheme (1971-1980) for the Allocation of Production Forces play an important role. It would be very informative if the Soviet delegates could give us additional information on these documents. In particular we would like to know the following: What stage of elaboration have these documents reached? How do they interact with the five-year plan of the USSR? What is the status of TPCs in these documents? What influence have these documents had on the past and present development of the BITPC? What is the procedure for the permanent updating of these documents? Are there variants and/or strategies in these long-range documents?

At the twenty-fifth Congress of the Communist Party of the Soviet Union, TPCs were discussed. It was generally agreed that improved methods are needed for solving large-scale problems in several branches and regions. A single, coordinated central program covering all stages from design to practical realization of such large tasks was called for. The formulation and implementation of such programs must be based on a unique management system. It appears that the Soviet leaders consider the further improvement of the management and planning procedures of TPCs as an important, integral part of improvements to the overall system of management and planning.

In the elaboration and implementation of a regional program, account should be taken of the fact that many enterprises--mainly

industrial--are planned and directed by leading bodies outside the region. In the USSR, for example, many enterprises and factories are run by a Union Ministry. Many local problems have to be settled by the local governmental authorities. In this context we would also like to know more about the following: What interaction is there between local and central or centrally-controlled organizational management units in the planning and implementation phases? What is the method for resolving conflicting interests (related, for example, to problems of housing, siting, waste disposal, environmental protection, increase in the number of employees)? What are the financial arrangements between local authorities and centrally-planned enterprises?

In the planning process the opportunity of choice plays an important role, and information about alternative strategies gives insight into a certain program. For this reason, it would be very helpful to obtain detailed information about alternative strategies or variants for the BITPC and about the selection of the current variant. In this connection we would like to know the following: Were there any other alternatives to the Bratsk-Ilimsk Program? What is the procedure for variant selection? What criteria are used? What criteria are used for the allocation of specialized production, which is of national importance, in case of two or more different sites with similar natural resource deposits? Have there been or are there different concepts for the development of the BITPC? Who decides these and how? Are documents available giving a comprehensive description of the plans of the BITPC?

We look forward to having an interesting and fruitful discussion and to exchanging ideas and experiences.

I would like to thank the authors of the Conference papers, their institutes, and the USSR State Committee for Science and Technology, for the excellent work they have done to make this Conference possible.

Long-Term Planning in the USSR and
Decisionmaking for the Development of the BITPC

L.I. Gramoteyeva

PLANNING SYSTEM IN THE USSR

In the USSR, the planning of the national economy is the central link in the overall system of scientific management of the socialist economy. The system of planning bodies of the national economy includes central and local general planning bodies, headed by the State Planning Committee, and a ramified network of departmental (managerial) planning organs subordinated to the general planning bodies. The system of planning bodies is responsible for formulating national economic plans for the development of overall social production and that of individual sectors.

The coordination of social and economic interests is one of the most important features of national economy planning in the USSR.

In accordance with the Constitution of the USSR, development plans of the Soviet economy are considered and approved by the Supreme Soviet; in the Union and Autonomous Republics, this is the function of the Republic Supreme Soviets, and in the territories, regions, districts and cities, local organs of state power are the responsible bodies.

Draft plans are worked out by the top executive bodies, i.e., the Council of Ministers and the Councils of Ministers of Union Republics, and are submitted for approval to the Union and Autonomous Republics.

The planning of the Soviet national economy is based on the principle of coordinating the centralized plan, which sets basic growth rates and goals for economic development, and the independent activities of local bodies, territorial-production associations and enterprises which design measures for achieving these goals.

Centralized plans, worked out and endorsed at all levels of economic management, have the characteristic of a directive. The obligatory nature of approved planned assignments is combined with the use of economic levers--price controls, credits, allotment of a share of profits to the funds of enterprises and amalgamations, bonuses, etc.--as incentives for fulfilling national economic plans and raising the efficiency of social production.

The development of the national economy based on centralized planning makes it possible to rationally combine branch and territorial planning, and to take into account the regularities in the territorial division of labor. Rational planning of the territorial structure of social production is important in the country which has 15 Union Republics and 19 large economic regions that extend over a vast territory.

The substantiation of the branch and territorial structure of production is an important aspect of the economic development plan. For example, the plan contains directions about the rate of regional economic development, capital construction, labor force requirements, and living standards of the population.

Coordinating current and long-term planning, with long-term plan playing the major role, has been an important feature of national economic development plans at all levels in the USSR. This principle formed the basis of the country's first long-term plan, the GOELRO, formulated in 1920, and has been incorporated in the subsequent activities of the State Planning Committee. At the 1926 Congress of the Presidiums of the State Planning Committee, three main functions of socialist planning were defined: elaborating the Master Plan for the reconstruction of the national economy for 10 to 15 years; drawing up a long-term plan for a five-year period; and estimating figures for the next fiscal year. Currently, broadening the scope of the Master Plan is a major requisite for its influence on the country's social production.

The growing maturity of the Soviet economy and culture makes it possible to deal with complex scientific, technological and socio-economic tasks. Their solutions, as a rule, go beyond five-year plans and call for the development of long-range forecasts of social requirements and production. Long-term planning, in this case five-year plans, allows one to establish goals for further development, solve major technological and socio-economic tasks in stages, and implement large-scale comprehensive programs. Such a system of planning ensures continuity of planned targets, lessens the influence that existing trends have on the development and allocation of productive forces, broadens the choice of economic solutions, and makes it possible to use modern methods of planning the national economy.

PLANNING FOR THE BITPC

The drawing up of large-scale comprehensive regional programs is one of the most important means for improving the development of new territories and for increasing the efficiency of social production in these regions; this is especially important for territories in Siberia, the Far East and the Far North.

Currently, a long-term plan for national economic development for the period 1976-1990 is being drawn up. Large-scale, comprehensive intersectorial, interregional programs are being developed as the most important part of this plan. For example, the plan includes a program for the use of resources of the Kursk Magnetic Anomaly, an intersectorial program for agricultural growth in the nonblack earth zone of the European part of the USSR, a program for the development and comprehensive use of oil and gas resources in the West Siberian plain, and a program for the optimal use of fuel and power, mineral raw materials, and water and timber resources of East Siberia.

The development of the Bratsk-Ilmsk Territorial Production Complex (BITPC) is another example of a program of this type. The BITPC is of national importance since it has developed highly effective power resources in the eastern regions of the country, and created large-scale power-intensive industries that are the main link in the countrywide specialization of the complex. On a nationwide scale, this means identifying possibilities for improving the fuel and power balance in the European part of the country. The BITPC makes an important contribution to increased economic efficiency of social production. For example, because of the power-intensive industries located there, it has been possible to realize an economy of about 10 to 12 roubles per ton of conventional fuel; moreover the production cost of one ton of aluminium is approximately two times less than that in the European regions of the country.

The development plans of the BITPC include several stages; among the major ones are the following:

- Analyzing the current level of economic development of the region; evaluating the technological, economic, social, and natural conditions and requisites for forming the rational structure of the BITPC;
- Selecting and substantiating the aims set by the centralized plan for an appropriate planning period with relation to the BITPC; defining the general scientific approach for achieving economic development and solving key socio-economic tasks;
- Formulating a coordinated system of economic and social measures for efficiently achieving the goal set; determining the production levels, the intersectorial structure of the BITPC and the rational forms of the internal organization of economy;
- Reconciling and coordinating branch and territorial aspects of the economic development of the BITPC; coordinating a stepwise system of planned targets set for the intersectorial complex with the general national economic plan for the same period.

- Forecasting new technological, economic and socio-economic trends and economic situations in the BITPC.

At the initial stage of the Region's development, information is obtained on social production, major industries, and increases in living standards since the last planned period. Analyses of the data indicate areas for improving production growth rates and efficiency, and for detecting bottlenecks and shortcomings in the comprehensive development of the economy. The summing up of the results of the preceding five-year plan and the analysis of the results of the initial stage are usually done on the basis of the following economic and social indices: the gross output of industry and agriculture, the amount of capital investments, average monthly wages and salaries of waged and salaried workers, and indicators of the efficiency of material production such as labor productivity, returns on assets, and quality of goods produced.

Let us examine the development process of the long-term plan for the Bratsk-Ilimsk Complex. A number of principles underlie the elaboration of this plan. A head organization is selected for elaborating and scientifically substantiating plans for the development and allocation of the productive forces in the country and in individual regions, including the BITPC which serves as a coordinating center. This organization then enlists the assistance of appropriate institutes and government ministries and departments; obtains finances for the work based on the government plan; provides a uniform approach for drawing up the program; and oversees the phased implementation of the program that incorporates the most essential targets and indices of the national economic plan. As regards the BITPC, a dynamic model of economic growth of the Region has been used; programs for solving individual branch, regional and general economic problems are the components of the general model of the Region.

The hypothesis is developed in four stages. The first stage is the formulation of a general scientific concept reflecting the aims and directions of the economic and social development of the Region as part of the national economy; the concept serves as a connecting link between long-term, medium-term, and current plans.

The second stage is the elaboration of the basic directions of economic growth of the Region, and the elucidation of its major technological, production, economic and social problem areas and their coordination within the framework of the national economic plan.

The third stage is the development of a comprehensive intraregional scheme for industrial growth and location of production in districts, industrial centers and production complexes, taking into consideration such factors as the existing settlement pattern, regional conditions for rational manpower utilization, and the economic use of natural resources.

In the fourth stage there is substantiation of various versions of intersectorial, intraregional development of the productive forces of the region, using a system of mathematic models of economy to select an optimum version that synthesizes branch and regional development plans of the BITPC.

In the formation and implementation of the long-term development plan of the BITPC, account is taken of the need to maintain continuous proportional growth and a constant balanced development of various sectors of the productive and nonproductive sphere, maintaining a comprehensive intraregional development of the productive forces and a greater efficiency of social production.

Special attention is paid to substantiating the development rate of that production sphere whose sectors rationally use local natural resources.

These objects of the complex are singled out as objects of its specialization, i.e., key industries are created for the joint fulfilment of the plan for national economic development. The productive capacities of such industrial objects are part of a state system of interconnected and interdependent sectors of production that features a proportional development. The substantiation of the development of these sectors involves a comparative techno-economic evaluation of various areas for their location, with due account of the links between the given industry and related production sectors. Versions of the formation of the production complex, by fields of specialization, are worked out on the basis of its vertical (productive, technological) and horizontal (product marketing) connections. The unity of productive-territorial ties and the completeness of the production cycle ensure, as a rule, cost savings, and are a major factor in raising the economic efficiency of production.

The horizontal ties of a production unit make it possible to calculate the expense of transporting finished products to markets; such ties should also be taken into account in evaluating possible variants of the territorial distribution of industries.

The intersectorial complex of specialization on the territory of the BITPC has been created on the basis both of technological (vertical) ties (e.g. production of electric power and electrolysis of aluminium, felling and transportation of wood and woodprocessing) and of the territorial unity of the sources of raw materials (e.g., hydroresources, coal, forests).

The development prospects for various fields of specialization of the BITPC are elaborated with due regard to rational interregional ties required for marketing finished products; hence, they also take into account horizontal ties. Currently, the main products of the complex (e.g. electric power, wood, iron-ore concentrates, aluminium) are extensively exchanged for commodities produced in other regions.

The accelerated construction of the Bratsk hydropower station (HPS) called for the coordination of deadlines for the beginning and the completion of the construction of the Bratsk aluminium plant, which is the main consumer of electric power in this area. As a result of such coordinated decisionmaking expenditures have been cut by approximately one-third as compared with those that might have resulted in the case of uncoordinated decisions. Such estimates are used to determine the most important indices characterizing the process of the formation of an intersectorial complex, namely general deadlines of construction, schedules for the simultaneous commissioning of individual objects and their component parts; planned time-coordinated organization of construction and assembly work within the framework of the complex; compilation of annual balances of manpower requirements for building the objects, and labor balances required for the exploitation of these objects.

These indices provide the objective prerequisites for, and initial data on, the further promotion of the territorial-production structure of the complex. We refer here to the development of auxiliary branches of production, the most important of which are the following: a program for developing the capacities of the construction base; a program for setting up integrated power facilities aimed at meeting the heat and power needs of industrial and communal enterprises; a program of external and internal transport construction; a program for creating a single repair shop system; and a program for industrial and urban water supply and environmental protection.

In accordance with the scheme adopted for the formation of the BITPC, each of the programs has defined functions, and the complex as a whole has a complete territorial-production cycle.

In forming the territorial structure and in determining development levels of the BITPC, account is taken of its permanent ties with the long-term national economic plan. Thus, the evaluation of natural and manpower resources in the Region depends on the prospects for the formation of countrywide balances for corresponding resources. A comparative techno-economic evaluation of the efficiency of using various kinds of raw materials, fuel, power, timber and water resources in this and other regions is carried out in accordance with All-Union indices. In ascertaining long-term scales, structure and development levels of various sectors of material production in the Region, attention is paid to coordinating these with the optimal plans of Union ministries and departments for the development and location of respective branches of production.

The creation of large production centers with narrow sectorial specialization and highly concentrated industries is typical of the development of the territory of the Bratsk-Ilimsk Complex. Currently, three such production centers have been established; the largest is the Bratsk Center whose development was influenced mainly by the construction of the

Bratsk HPS, an aluminium plant, a timber industry complex, a ferro-concrete construction plant and repair shops. The town of Zheleznogorsk is an iron-ore mining center, and another town, Ust-Ilimsk, is being built mainly as a power producing center.

A "production center" is defined as an intersectorial complex set up on a compact territory as a single economic unit, with balanced development of various productive and nonproductive sectors providing for a highly efficient territorial organization of the productive forces.

A major source of economy in developing the program for the internal organization of the BITPC is a specific organizational pattern of the productive forces, which provides for rational schemes for combined and cooperative efforts; standardized engineering structures and communications; common economic ties developed through joint auxiliary and servicing industries; an integrated construction industry, power and water supply systems, transportation system, etc.

The group location of production units creates more favorable conditions for improving the system of human settlements, for rationally using the labor force with due regard to the sex, age, and occupational composition of the population, and for better satisfying the material and cultural needs of the people.

In the creation and development of the BITPC, calculations have been made at each level to determine the territorial and intersectorial organization of production, and alternative economic situations are analyzed to find the optimum, attention is paid to their methodological and practical comparability. Versions are comparable if: the accepted methods of cost evaluation are identical; all elements of expenditures are taken into account in compliance with a common comparable list; initial information is handled using a single principle; and in all versions products perform the same role in satisfying society's requirements, or are interchangeable.

For evaluation and selection of an optimum scheme for the comprehensive development of the productive forces of the BITPC, mathematical models are used that make it possible to analyze the efficiency of the complex's territorial organization in terms of its effect on the future development of the national economy.

The comprehensive Master Scheme for developing and locating the productive forces for the period 1971-1980 at the national level is almost complete; 600 research, design and planning organizations and 20,000 scientists and engineers from the USSR have participated in its preparation. The Scheme is a scientifically substantiated document determining the prospects for economic and cultural development in the Union Republics, economic regions, regional economic and territorial-production complexes; it is part of the economic planning system. The Scheme

provides the basis for making stepwise planning decisions for the allocation of various industries and the comprehensive development of regional economy.

The Master Scheme outlines prospects for setting up and developing the BITPC for the corresponding planned period. The construction of the Bratsk HPS is the most important stage of planned decisions for the region. The Bratsk station is one of six possible stations of the Angara cascade; the first four units, each with a capacity of 225,000 kW, were commissioned in 1961. The main structures of the hydroengineering complex--the dam, the power house, bus-and-switch structures, and bridge passes--are compactly situated in a narrow 5 km strip.

Power production and power-intensive industries form the base of the region's complex. The decisions to construct in the plan period 1958 to 1965 the Bratsk aluminium works and a woodworking complex marked the beginning of the simultaneous commissioning of power capacities of the Bratsk HPS. All the units of the Bratsk aluminium works, which number about 40, are situated on a vast territory of 160 hectares; the first metal was produced in 1966.

The woodworking complex has 12 units, eight of which are engaged in wood processing. This project was to be fully operational during the eighth five-year plan period.

In the course of building major units of the complex, several new auxiliary objects appeared.

The development of the iron-ore industry at the BITPC has national importance since it is part of the national plan to develop the third metallurgical base of the country. Favorable transportation ties and considerable amounts of ore in the Korshunovo deposit have determined the stepwise development process of the Angara-Ilmsk iron-ore basin. Comparatively rich resources of this deposit, good quality ore and favorable conditions for bedding have facilitated the establishment of cheap open-cast mining here. The Korshunovo ore-dressing plant has been operational on the basis of this deposit since 1971; its annual capacity is estimated at 12 million tons. Currently, iron-ore concentrate is shipped to West Siberian metallurgical works. The creation of metallurgical capacities (e.g. Taishet metallurgical integrated works) is envisaged in the Region itself, and an additional deposit will be commissioned.

Prior to the completion of the Bratsk HPS, it was decided to build in 1962 the Ust-Ilmsk hydropower station, with a capacity of 4.3 million kW, as the second stage in the development of the Angara water power resources. The prospects of exploiting a new big source of power have entailed the formation of additional basic objects--consumers of power--and several auxiliary and servicing objects. However, the production pattern of the BITPC will continue to be determined by electric

power production, nonferrous metallurgy and the woodworking industry, although in the foreseeable future it is envisaged to manufacture synthetic fiber and to produce chlorine using cellulose and local deposits of common salt.

The problems of creating and developing auxiliary and servicing branches of the economy are being tackled successfully along with other economic problems. Large-scale industrial development of the Region has brought about the rapid growth of the building materials industry. On the territory of the BITPC, building materials are being manufactured. Thermal and electric power production is being developed on the basis of local coal. Several heat and power plants supplying heat to large towns and industrial enterprises of the complex are operational.

The power supply balance of the BITPC is expected to be positive for a long time. Therefore, the network of power transmission trunk lines will be expanded by developing both intraregional and interregional connections. Currently, electric power is being transmitted from the Bratsk HPS to the industrial centers of Zheleznogorsk and Ust-Ilimsk, and also to the vicinity of Irkutsk and the Krasnoyarsk territory, through 500 and 200 kW transmission lines.

Based on current knowledge, it is possible to conclude that future large-scale demand for thermal and electric energy will be fully met in the future. The techno-economic indices of the energy use for the Region will show a major cost savings for power as compared with European regions.

The BITPC is also characterized by favorable conditions for the rational formation of water balance. Water is supplied for utility and industrial purposes both from surface and sub-surface sources, the principal sources being the Bratsk and the Ust-Ilimsk reservoirs, the Angara River and its tributaries, and several small rivers.

Conditions for the development of a broad transportation network are less favorable for the BITPC for the following reasons. First, the complex is remote from the most advanced and populated areas of the country; it is about 4000 km from the nearest European region of the country, and cargo deliveries to the territory involve great transportation expenses. Secondly, it has geographic proximity to comparatively sparsely populated regions that have not only limited industrial potential for interregional exchange but also inadequate communication lines.

Nevertheless, in accordance with the policy for intraregional formation of industrial centers, efforts are being made to improve and develop the transportation network as one of the major elements of the productive and social infrastructure. The Bratsk industrial center, as an area of top priority development, is already a major transportation junction for many

railway stations, rivers, airports, and motor depots. The Bratsk airport is able to handle large aircraft from throughout the country. Bratsk is connected by air routes with many towns and populated areas on the TPC territory.

The construction of a ramified network of access routes, railways, and motor roads is carried out in coordination with industrial and urban construction on the territory. An urban electric train operates between the Bratsk center and the aluminum works.

Public transport is represented by the trunk railway line, Taishet-Lena, and its continuation from Khrebtovaya to Ust-Ilimsk. The main motor road stretches from Tulun to Bratsk and Osetrovo. There is considerable traffic along the Bratsk-Ilimsk road. Transport connections are inadequate in zones of industrial forestry centers, although these centers were set up in locations with favorable water ways. Timber now accounts for about three-fourths of all river cargo. Air transport is well developed; the total length of local air routes exceeds 4000 km.

The development of the productive forces of the Bratsk-Ilimsk Region will largely depend on improvements and advancements of the transportation system in line with economic and social requirements.

An important and as yet unresolved problem for the Bratsk-Ilimsk Region and other complexes of the Angara-Yenisei system is that of attracting and settling manpower. This will involve the creation of attractive living conditions. Taking into account contemporary population density and the demographic situation, we can say that prospects for indigenous population growth are not great. Therefore, the program for the supply of manpower to the BITPC over the period 1971 to 1980 focuses attention on resettlement from other regions, and population migration will continue to play the decisive role in supplying manpower in the future.

A distinctive feature of the development program for non-productive industries at the BITPC is that it should be based on national norms for the provision of services, taking into consideration regional specific conditions with the aim of retaining a permanent labor force in the Region. The resettling of the labor force involves considerable expenditures. In addition, the severe natural and climatic conditions of the Region make the provision of food, clothing, housing, medical and cultural services more expensive than in more favorable areas. It is therefore necessary to further centralize the financial and material resources to attain an accelerated development of the social infrastructure of the Region.

The general plan for the urban development of the Bratsk complex envisages cultural, municipal, and medical services, which have been provided. Schools, libraries, theatres, clubs, music facilities, etc. have been made available to the population.

The further development of eastern and northern regions of the country is a subject of importance to those considering five-year economic development plans for the USSR.

The Contribution of the BITPC to Solving Long-Term
Development Problems of the Angara-Yenisei Region

V.A. Shelest

An important way to ensure the development of the USSR national economy and to improve the efficiency of public production is to develop and rationally use natural resources in those areas where they are abundant, to set up highly effective territorial-production complexes in these areas, and to formulate and implement long-term, regional, and national economic programs.

Long-term scientific and technological forecasting and planning are needed to deal with the problems of integrating the development of natural resources and productive forces on the regional level. Solutions to these regional problems largely determine the growth of the national economy and its industries as well as the specialization and integrated economic development of large territories. Regional programs take into consideration natural, social, economic, scientific, and technological factors, and employ methods of systems analysis. The regional system is an integral part of the overall national economic system.

In the Soviet Union, one major long-term regional program being worked out is that for the use of natural resources and the development of the productive forces in the Angara-Yenisei Region, which includes the Krasnoyarsk territory, the Irkutsk Region, and the Tuva Autonomous Republic.

The Angara-Yenisei Region is unique in its concentration of natural resources. While it accounts for only 15 percent of the territory of the USSR and 2.2 percent of population, the Region has about 50 percent of the country's coal resources [1, pp.111-112], over 30 percent of its wood resources, and over 25 percent of the water power potential [2, pp.52-53]. It also has practically unlimited rock salt resources, enormous nonferrous metal ore deposits, and vast amounts of resources such as iron ores, phosphorites, graphite, and construction materials. The geological coal reserves of the Kansk-Achinsk, Tunguska, Irkutsk, Minusinsk and other coal basins have a total of 3.36×10^{12} tons. The Angara-Yenisei water basin has an annual water runoff averaging 623 km^3 , and a hydropower potential equivalent to 600 kWh of annual electricity output. The Region is also rich in lead-zinc deposits, nepheline deposits, etc. A natural treasure is Lake Baikal [3, p.39].

These resources appear to be all the more valuable because of the very favorable techno-economic indicators regarding their use. In the Region, costs are higher for certain products and services, e.g., construction costs in the southern and central areas is 2 to 8 percent higher than the national average, and in remote areas it is 15 to 25 percent higher; equipment costs are 3 to 8 percent higher. Also, there is a sizable share of capital outlay for social infrastructure--in the southern and central areas it rises by 5 to 15 percent, and in the remote areas it is 1.5 to 2.5 times the national average. On the other hand, the Region's estimated expenditure in the foreseeable future will be less than those for the European part of the country for the following areas: lumbering, woodworking, and pulp and paper industries (30 to 60 percent); for the manufacture of energy-intensive products from nonferrous and ferrous metals, as well as products of the chemical industry based on the use of local raw materials (1.5 to 3 times the national average); for coal output increment this figure is 6 to 8 times the national average, for electric power output increment, 2 to 2.5 times (and at hydropower stations, 3 to 4 times).

In the future the Region will lead the country in coal and electricity output, and in the manufacture of energy-intensive products of nonferrous metals.

Based on the development prospects for the national economy and taking into account the Region's natural resources and the good economic prospects for their efficient use, some fundamental concepts for developing the Angara-Yenisei Region have been formulated.

The availability of natural resources and the favorable techno-economic factors of their development and use determine the specialization of the Region's economy for developing energy-, material- and water-intensive branches. Of primary importance are those resources that have high national economic significance and are concentrated in the Angara-Yenisei Region. Accordingly, priority has been given to the development of nonferrous metallurgy.

In the second group of resources that influence the Region's specialization are those that are also available in the other areas of the country, but whose development in the Angara-Yenisei Region is more economically feasible. These include fuel coals which can be mined by certain methods on a scale not possible in other regions.

The third group is composed of those resources whose utilization is compatible with the development of other resources. These include zinc, bauxites, iron ores, apatites, phosphorites, and phlogopites. Classed under the same category are resources supplied to the Region from other areas; these include bauxites and phosphorites.

Thus, the branches can be tentatively arranged in the following order in terms of feasibility and efficiency of development and distribution: nonferrous metallurgy; the coal industry (the development of fuel brown coals in the Kansk-Achinsk coal basin plays a major role in the national fuel energy program); electric power engineering (construction of major thermal coal dust and hydropower stations); lumbering, woodworking, and pulp and paper industries; graphite production; the mica-production industry; chlorine production based on the use of rock salt resources; extraction of apatites and phosphorites, and production of phosphorous fertilizers; production of asbestos, magnesites, and optical raw materials; production of electric furnace steel and ferroalloys; antimony and mercury production; production of construction materials; cast iron and steel production; metal-intensive engineering; and food and light industries.

Allowing for extra expenditures for developing the territory, the output of net products per unit cost in the Region is likely to be higher than that in the European part for nonferrous metallurgical products by about 30 to 50 percent, for the chemical and woodworking industries, by 10 to 20 percent and for light industries and engineering industries, by about 10 to 15 percent and 15 to 25 percent, respectively.

Other factors that are taken into account in determining the specialization of the economy of the Angara-Yenisei Region are population density, construction conditions, and living standards. The general development trend seems to be as follows: in the area from Khakassian to the southern areas up to the Yenisei middle course, there should be a steady increase in the energy-intensiveness of the enterprises. Labor-intensive industries such as material processing, power engineering, transportation and road building, and highly efficient agro-industrial activities must be set up primarily in the southern part. The energy-intensive industries such as aluminium plants, plants for producing yellow phosphorus, ferroalloys, and electric furnace steel could be more conveniently located farther northward, for instance, in the territory of the Kansk-Achinsk fuel-power complex and in proximity to the hydropower stations on the Angara and the Yenisei Rivers.

The general line of economic development of the Angara-Yenisei Region in the surveyed period is intensification of public production. In outlining the strategy for the long-term technological development of the Angara-Yenisei Region, and Siberia as a whole, one must consider the gap between available concentrated natural resources and scarce manpower. In terms of extensive development, it does not appear promising in the Region.

Some decisive factors for achieving the extensive development of natural resources and higher efficiency of public production in the Region are as follows: creation of an optimal sectorial and territorial structure of the economy; implementation

of labor-saving technological and economic policies; concentration of production; increase in the amount of energy and electricity available per worker; large-scale development of electric-based manufacturing processes; further electrification of the national economy; utilization of useful ingredients contained in the ores; technological combination and cooperation; reduction of losses; and improvement of the territorial organization of production.

A criterion for the rapid and effective development of the productive forces in the Region is to set up a reliable productive infrastructure (power engineering base, construction materials industry and construction base, transportation, water supply, etc.), and a nonproductive infrastructure (housing, health services, social-cultural facilities, etc.).

To effectively use both the natural and human resources of the Region, it is necessary to plan and create major common territorial-industrial complexes and energy-industrial centers rather than isolated enterprises. Thus in order to ensure the growth of the Region's productive forces it was decided to establish the Bratsk-Ilmsk Territorial-Production Complex (BITPC).

The prerequisites for establishing and developing the BITPC are the availability of cheap electric power from the Bratsk and the Ust-Ilmsk hydropower stations (HPSs), the concentration of commercial deposits of iron ores rich in iron content and readily concentrated, and large timber, land and water resources. A powerful construction industry has helped to accelerate the development of the Region's productive forces.

The construction of the Bratsk HPS served as a basis for developing the BITPC. The Bratsk station, the second stage in the Angara cascade, was built at the Padun narrowing; its normal affluent level is 402 m, and the difference in the levels is 108 m. The dam raises the water level in the Angara by over 100 m. The Angara basin area within the range of the Bratsk HPS is about 740,000 km², and the average long-term discharge is 2906 m³ per second [2, pp.437-439]. The reservoir of the Bratsk HPS was formed in the Angara River Valley, its water surface being about 5400 km². The reservoir's width varies from 3 to 20 km. During the construction of the reservoir, the local population was moved from the flooding zone to new modern settlements; a number of enterprises have been moved to other sites and completely modernized; rehabilitation of agricultural production has involved reclaiming state forest fund lands and combining small farms into large state collective farms. The new reservoir made it possible to develop water transportation over a distance of 1300 km. Reproduction of fish resources is done by constructing sturgeon breeding farms and developing fisheries in the reservoir. The total volume of the Bratsk HPS reservoir is about 170 km³ and its useful volume at 10 m draw-off depth is about

50 km³, i.e., about one-half the average annual discharge in the range of the hydroproject.

The structures of the hydroproject are a concrete riverbed dam, an embankment and an earth dam, and the HPS building. The first power sets at the Bratsk HPS were put into service in 1961. Currently, the Bratsk HPS has 18 turbosets with an aggregate generating capacity of 4.1 million kW, providing for electric power output in a median year as high as 22.6×10^9 kWh [4]. Operating in conjunction with the Irkutsk HPS reservoir, the Bratsk reservoir makes it possible to control the Angara water region and to carry out an inter-basin control of the discharge at the Angara and the Yenisei HPSs. The Bratsk HPS is one of the main power stations in the Integrated Power System of Central Siberia and, therefore, its operating conditions are determined by the optimum conditions of the joint operation with other power stations of the grid. Navigable depths in the Angara lower reaches and on the Yenisei below the Angara mouth are secured by the corresponding flows from the Bratsk reservoir in the navigation period.

The construction base of the Bratsk HPS served as a basis for building the Ust-Ilimsk HPS and, later, the Boguchany HPS on the Angara. The Ust-Ilimsk HPS, the third stage of the Angara cascade, is now under construction; its normal affluent level is 296 m, and the difference in the levels at the station is 88 m. The Ust-Ilimsk HPS is hydraulically linked with that of the Bratsk HPS, since the Ust-Ilimsk HPS backwater reaches as far as the Bratsk hydroproject tailwater. Inflow to the HPS site is largely controlled by the reservoirs of the Irkutsk and Bratsk stations. The Angara lateral inflow between the Bratsk HPS site and that of the Ust-Ilimsk HPS is less than 10% of the Angara average annual discharge at the Ust-Ilimsk station site. The estimated total volume of the Ust-Ilimsk HPS reservoir is 60 km³, and the estimated useful volume for a 1.5 m draw-off depth is 3 km². Its rated capacity will be 4.3 million kW, and the annual electric power output will be 21.6×10^9 kWh [2, pp.437-439].

The construction of the Bratsk and the Ust-Ilimsk HPSs has accelerated the economic development of the Angara-Yenisei Region. Bratskgesstroi, an organization originally set up to undertake the construction of the Bratsk HPS, is also responsible for constructing all the industrial projects in the Region. A powerful construction industry base exists with precast ferro-concrete plants, woodworking plants, factories producing metal structures, sanitation equipment, etc.

The Angara-Ilimsk Region comprises the Ilimsk and the Angara-Katsk groups of iron-ore deposits. In terms of quality, the ores are similar to self-fluxing ores; rich ores at the Rudnogorsk deposit can be used without concentration. Leaner ores can be satisfactorily concentrated by means of wet magnetic separation.

The largest Korshunovo deposit is exploited by the West Siberian Metallurgical Works. It is planned to put the Rudnogorsk deposit into service. In the Angara-Katsk group, exploration of the Neryundino deposit has been completed. The Angara-Ilimsk iron-ore district is regarded as a possible base for a future iron and steel plant.

The Angara hydropower resources provide cheap electric power in mass quantities; thus the Irkutsk Region is regarded as favorable for setting up aluminium plants, despite the fact that the required raw material is not available locally. The city of Bratsk is becoming a major center for the aluminium industry. To reduce transportation costs, it would be expedient to establish the Region's own production of aluminium-rolled stock and aluminium structural components.

The Bratsk-Ilimsk Region has large tracts of high quality wood. Once the Bratsk HPS was constructed, it was possible to set up enterprises for complex timber processing. Thus, in Bratsk the construction of a large timber industry complex with producing facilities for pulp, cardboard, wood-fiber boards, sawn timber, nutrient yeasts, etc. is nearly completed. The strengthening of the raw material base for the timber industry complex calls for improved transportation facilities in the Region. The Khrebtovaya-Ust-Ilimsk railroad is operating, and construction work has begun on the western section of the Baikal-Amur Railway.

It seems reasonable to set up near the town of Bratsk a large agricultural complex for vegetable, meat and milk production.

The BITPC will be oriented toward hydropower engineering, energy-intensive production of nonferrous metals (e.g., aluminium), timber processing (with a wide assortment of products manufactured at woodworking, pulp and paper, and wood/chemical enterprises); later it is planned to have the chemical industry make use of the materials turned out by the pulp and paper mills (e.g., chemical fiber, viscose silk, and cellophane), and by the mining industry. Planned auxiliary industries include mechanical engineering and enterprises producing consumer goods. Iron ore will be transported to the iron and steel works in Central Siberia, and the products of nonferrous metallurgical industries, and the chemical and the woodworking industries will be transported to other regions of the country.

The BITPC includes three industrial centers: Bratsk, Ust-Ilimsk, and Rudnogorsk.

The Bratsk Industrial Center, the first in the region under consideration, is almost complete: there exist an HPS, an aluminium plant, and a woodworking complex. It is planned to expand the Center by developing the Region's iron-ore base, e.g., Tatyansinsk and Krasnoyarsk mining and ore-dressing plants, by constructing and establishing new enterprises as part of the woodworking complex and the aluminium plant, and by developing

new processing facilities such as a viscose fiber plant. From a town planning viewpoint, the Bratsk Center commands resources for further expansion because of the existing large capacity construction base and engineering communications, utility funds, and cultural and consumer services. In further developing the Center it is important to locate residential neighborhoods at sufficient distance from new industrial enterprises so as to prevent air pollution.

The construction of the Ust-Ilimsk HPS will double the power engineering capacity of the complex, and also give an impetus to a new industrial center specializing in lumbering, mechanical and chemical processing of wood, and iron-ore mining in the Angara-Katsk area. Consideration is given to building on the Center's site a city, thereby eliminating the need to construct small communities near the enterprises while effectively using the site on the Angara right bank in the upper pool of the Ust-Ilimsk HPS.

The Rudnogorsk Industrial Center can be regarded as a standby in the composition of the BITPC. Its territory has favorable building sites with adequate water supplies and transportation facilities. The planned structural layout of the Center makes it practical for creating a large-scale enterprise and a town.

Also part of the territory of the BITPC is a regular network of communities either existing and planned that are set up on the basis of forestry farms, state farms, or mining centers. The problems of providing transportation, cultural, consumer, and utility services for the population in the centers, as well as of organizing the settlement pattern in the pioneering region, are important and require urgent action.

The BITPC was further developed when the Ust-Ilimsk HPS became operational. Some additional criteria for development are as follows: commissioning power capacities at the Ust-Ilimsk thermal power station; building the Neryundinsk-Kopaevsk mining and ore-dressing complex; making provisions for developing further the aluminium production; increasing lumbering capacities on the basis of the forest resources in the Ust-Ilimsk, the Nizhne-Ilim, and the Ust-Kut forestry districts; reducing round timber deliveries to areas outside Irkutsk; effectively using pulp production wastes by setting up paper mills and a furniture factory; setting up facilities for mining fuel coals in the Tunguska field to be used at the BITPC; building meat and milk processing enterprises in the cities of Bratsk and Ust-Ilimsk; and developing fisheries in the Ust-Ilimsk reservoir.

Because of the natural wealth of the Angara-Yenisei Region, including the BITPC, it is important that scientific and technological solutions be sought to the Region's problems. Programs for the optimal utilization of natural resources and increased productivity of human resources should be an integral part of the long-term development plan.

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Experience in the Formation of the BITPC

V.P. Gukov and A.N. Semyonov

ANGARSTROI PROJECT

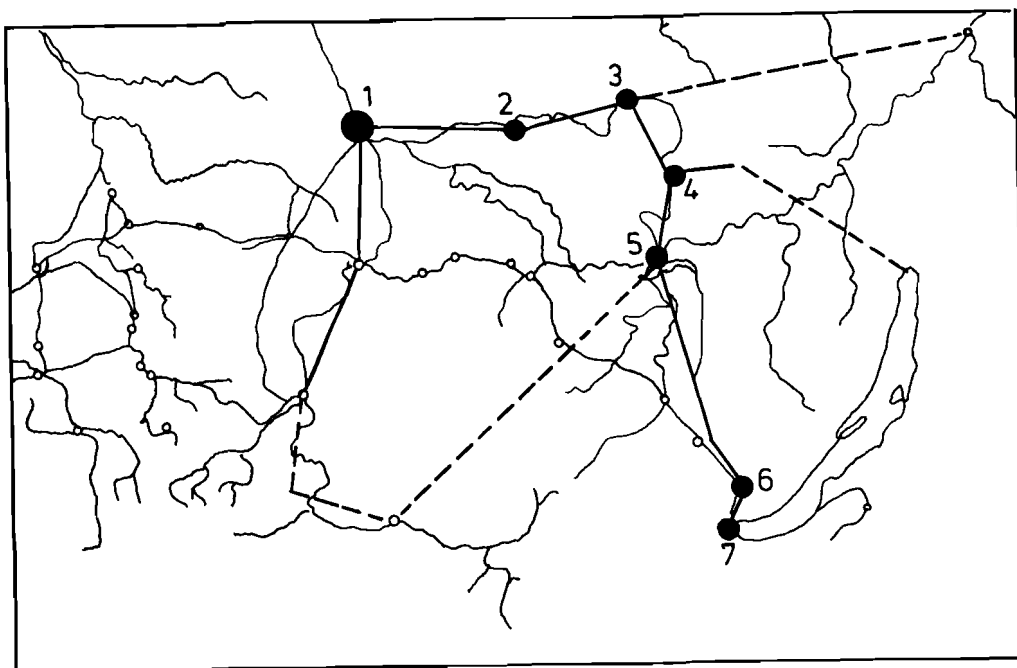
The idea of developing the hydropower resources of the Angara River and its tributaries originated in the early 1960s.

In 1925-1929, the Siberian Bureau of the USSR State Planning Committee, with the assistance of N.N. Kolosovsky and V.M. Malyshev, drew up an initial development scheme for using the hydropower resources of the upper and middle reaches of the Angara River. The plan envisaged the construction of three stations: the first 12 km from headwaters, the second on the Dubynin rapids, and the third on the Shaman rapids, with a total capacity of 3.5 million kW. It was also planned to build two industrial complexes in the region of the hydroelectric station: one at the headwaters of the Angara River, and the other near the big rapids in the middle of the River reaches. Based on this research, design plans were included in the first Five-Year Plan for national economic development.

A department of multi-disciplinary research (renamed the Angara Bureau) was set up in Moscow to study the problems of the Angara Region; later this became a center for organization and research.

In 1934, the research project, Hypotheses of Using the Power of the Angara River, was completed [1]. This work summarized the results of hydropower investigations, and gave information on studies by the Bureau on the use of minerals and forest resources, and the development of agriculture and transport.

The hypothesis reflected the progressive views of the time on the comprehensive use of raw materials and the multipurpose use of hydropower resources. It envisaged the construction of six hydroelectric power stations on the Angara River--Baikal, Barkhatovo, Bratsk, Shaman, Kezhem and Boguchany--with a total capacity of 8.95 million kW and an annual average output of 61.3×10^9 kWh of electric energy (Figure 1) [2,p.22]. After a careful study the Bureau recommended that the following power-intensive industries using cheap water power be set up in the Region: ferrous and nonferrous metallurgy, production of synthetic materials and liquid fuel from coal, nitro-hydrogenous compounds, chloride production, and silicate and aluminosilicate electrothermics.



- | | |
|-----------------|--------------------------|
| 1. Novoyenisei; | 6. Baikal; |
| 2. Boguchany; | 7. Kultuk; |
| 3. Kezhem; | — railways |
| 4. Shaman; | --- electric power lines |
| 5. Bratsk; | |

Figure 1. Location of hydroelectric power stations in the Angara Region.

The authors of the hypothesis believed that the construction of hydropower stations (HPSs) along the Angara River would open up broad prospects for developing the timber industry in the Region. The connection between the timber and the power industries was supposed to develop mainly through the coordinated construction of transport arteries and the provision of construction projects with timber. It was envisaged from the beginning to make comprehensive use of wood and to produce finished goods on the spot. Timber industry centers were to be located in the areas of the future HPSs where waterways would be crossed by railway lines.

Industrialization of the Angara Region is inconceivable without the adequate development of transport. On the one hand, the hypothesis envisaged the construction of super-long railway lines to connect the Region with other parts of the country. Also, they would bring the Soviet Far East closer to the economic centers of Siberia; therefore significance was attached to the railway line from Taishet, through the tailwater of the Bratsk HPS, and further east. On the other hand, it was envisaged to build long meridional railway lines for local freight traffic, which would make it possible to develop the timber industry, to work mineral deposits, and to build HPSs.

The plan was to develop grain growing and livestock in places of population concentration.

The hypothesis stressed the importance of working out the strategy and of establishing priorities for developing natural resources, primarily hydropower resources. All HPSs on the Angara River and its tributaries were divided into four groups according to efficiency, transport accessibility, and readiness of the regions for construction.

The first group consisted of the Baikal and the Barkhatovo HPSs on the Angara River, and the Kultuk HPS on the Irkutsk, which were planned to be built in the sufficiently advanced Baikal Region. Their aggregate annual output was estimated at 10.7×10^9 kWh.

The second group consisted of the most economical ones,--the Bratsk and the Shaman HPSs on the Angara River--which were planned to be built in an undeveloped region far from overland transport arteries.

The third group consisted of the Kezhem and the Boguchany HPSs on the Angara River, and the Taseyevo HPS on the Uda-Taseyeva, with a combined annual output of 24.4 million kWh. These stations were situated in a less inhabited and remote area, and are less economical than the Bratsk and the Shaman stations.

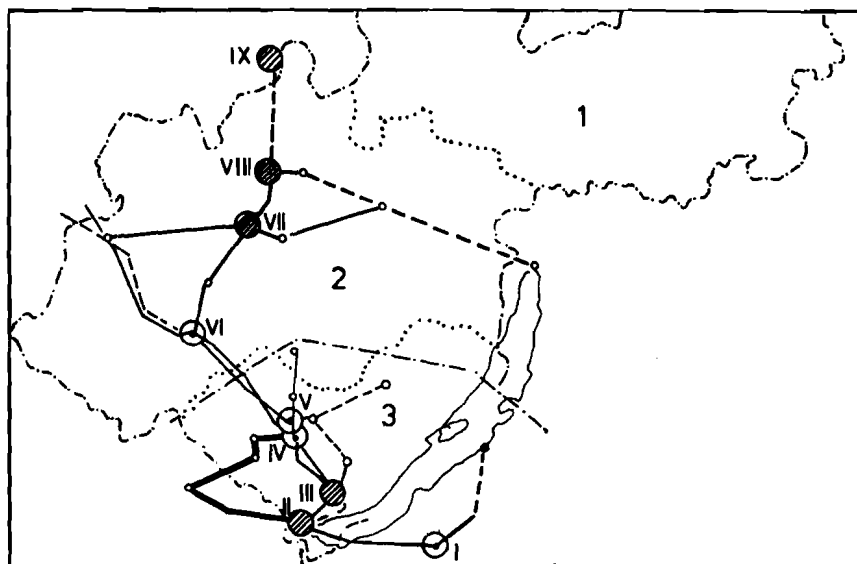
The fourth group included the least economical station--the Kibalin HPS on the Selenga.

During the period under review, because of insufficient information about the resources in the region of the third and fourth groups, it was not possible to substantiate the feasibility of constructing these stations with a view to creating industrial regions. Therefore the hypothesis focused on using the electric energy of the stations of the first two groups.

Undeveloped territory, remoteness from industrial centers, and inclement natural conditions prompted the authors to be careful in selecting the strategy for the industrial development of the Angara Region. Believing it unfeasible and inexpedient to begin with the construction of gigantic hydroelectric power

stations, they suggested that a "pioneer" industry be developed in the most accessible region. The aim of establishing this industry was to provide the subsequent, large-scale industrial construction activities with the necessary building materials, fuel and electric power, to accumulate experience and know-how on the severe climatic conditions and, to train personnel.

The first, most accessible and economically developed region was the Baikal--now the Irkutsk-Cheremkhovo TPC (Figure 2) [2,p.70] that has "a sufficiently dense population, crossed



- 1. Lena-Vitim power-economic subdistrict;
- 2. Sredne-Angarsk power-economic subdistrict;
- 3. Baikal power-economic subdistrict;
- hydroelectric power plants;
- thermal power plants;
- existing power transmission lines;
- planned power transmission lines;
- power transmission lines, 220,000 and 110,000 V;
- theoretical bounds of power-economic districts;
- ... bounds of power-economic subdistricts.

Figure 2. Power-economic districts and main power transmission lines in the Irkutsk Region.

lengthwise with a trunk railway line, having independent, though small-scale industry and prospects of using the Angara electric power" [1,p.180]. The presence of workable coal deposits made it possible to build the pioneer industry there on the basis of thermal energy, without connecting it with the implementation of the project for developing the Angara power resources. In the authors' view, it would be possible, by using thermal energy, to prepare the Baikal Region for the subsequent use of the cheap hydraulic energy of the Angara River. The pioneer industry was developed in the Baikal Region in the early 1930s.

It was the authors' opinion that since the mid-Angara Region and the Baikal Region, possessed the basic resources of cheap hydroelectric energy (57 percent), they were the determining factors in solving the Angara problem.

Selecting a top priority object of hydroengineering construction on the Angara, the authors noted that the Bratsk HPS was the most promising, from the point of view of its efficiency in the entire scheme.

The Bureau's work was confined mainly to drawing up a plan for constructing the Baikal industrial complex, specifying the structure of its industries, and planning industry and housing. In 1936, the team of experts of the USSR State Planning Committee approved the work of the Angara Bureau on the scheme of the Baikal-Cheremkhovo Complex.

The comprehensive investigations of the Angara problem by the Bureau exerted considerable influence on the development of the natural resources of the Angara Region. The planned formation of the pioneer industry based on energy produced by thermal stations working on Cheremkhovo coals began during the pre-World War II years; the war in 1941 interrupted the implementation of the Angara project.

After the war, studies of the Angara problem were continued. Since then new deposits of industrial raw materials have been discovered in the Angara Region. The economic potential of individual regions has changed and the need for the hydropower resources of the Angara River has become even more pressing. The level of possible engineering solutions has become higher, and the requirements for several types of products and the efficiency of their manufacture have changed.

In August 1947, the USSR Academy of Sciences held a conference in Irkutsk, chaired by Academician I.P. Bardin, on the productive forces of the Irkutsk Region. The conference resolution emphasized that "the basis for industrial specialization of the Irkutsk Region should be its hydropower resources (those of the Angara River) and fuel resources (the Cheremkhovo coal basin), and the leading role in the development of the region should be played by the energy of the Angara power stations" [3,p.106].

The conference focused on developing the Irkutsk-Cheremkhovo Region, which was the best prepared economically for developing the Angara hydropower resources. It was deemed expedient to build the Baikal (Irkutsk) HPS, to be commissioned in 1952-1953. The conference noted that by the time the first Baikal HPS was built, construction of other large HPSs should be started [2,p.107]. The Bratsk HPS was listed as a top priority project, and a railway line from Taishet to its dam site was already being laid out.

In 1949, a section of the Bratsk-Taishet Railway was temporarily operational which created conditions for implementing the Great Angarstroï project. In 1953, the Gidroproekt Institute involved a new scheme for hydropower engineering construction on the Angara River which envisaged the construction of six stations with a total capacity of more than 10 million kW, and an output of about 70×10^9 kWh (Figure 3) [4,p.21]. The Bratsk HPS was to be the most powerful. The Institute had evolved a schematic project for the Bratsk station, and specified its cost and the time required for its construction. Fully realizing that a HPS is needed only where there are power consuming industries, the project's authors, after comprehensive investigations, worked out a scheme for the industrial development of the zone of the Bratsk station's influence. This scheme defined the scope of the consumption of energy by major industries, their location and the direction of transport arteries. The organization of construction in the Bratsk station zone was thoroughly studied. It was thought expedient to create a single industrial base for building the Bratsk station and industrial and civil engineering installations in the adjacent region [5].

NATURAL RESOURCES OF THE ANGARA REGION

The Angara River combines three qualities important for power engineering: high water level, which is typical of rivers flowing through plains; impetuosity of mountain rivers, whose water discharge is usually not great; and the evenness of water discharge during the year, which can be explained by the regulating role of Lake Baikal.

At its outflow from Baikal, the River carries large masses of water-- 1950 m^3 per second. Owing to the replenishment from the tributaries, the stream's power increases rapidly amounting in the middle reaches to 2906 m^3 per second in the section line next to the Bratsk HPS, and to 3132 m^3 per second in the section line next to the Ust-Ilinsk HPS. The current is swift--0.9 to 1.5 m per second--which can be explained by a great fall of stream-- 20.4 m^3 per km. To compare, the respective figure for the Volga is 7 cm, and for the Dnieper, 9.8 cm.

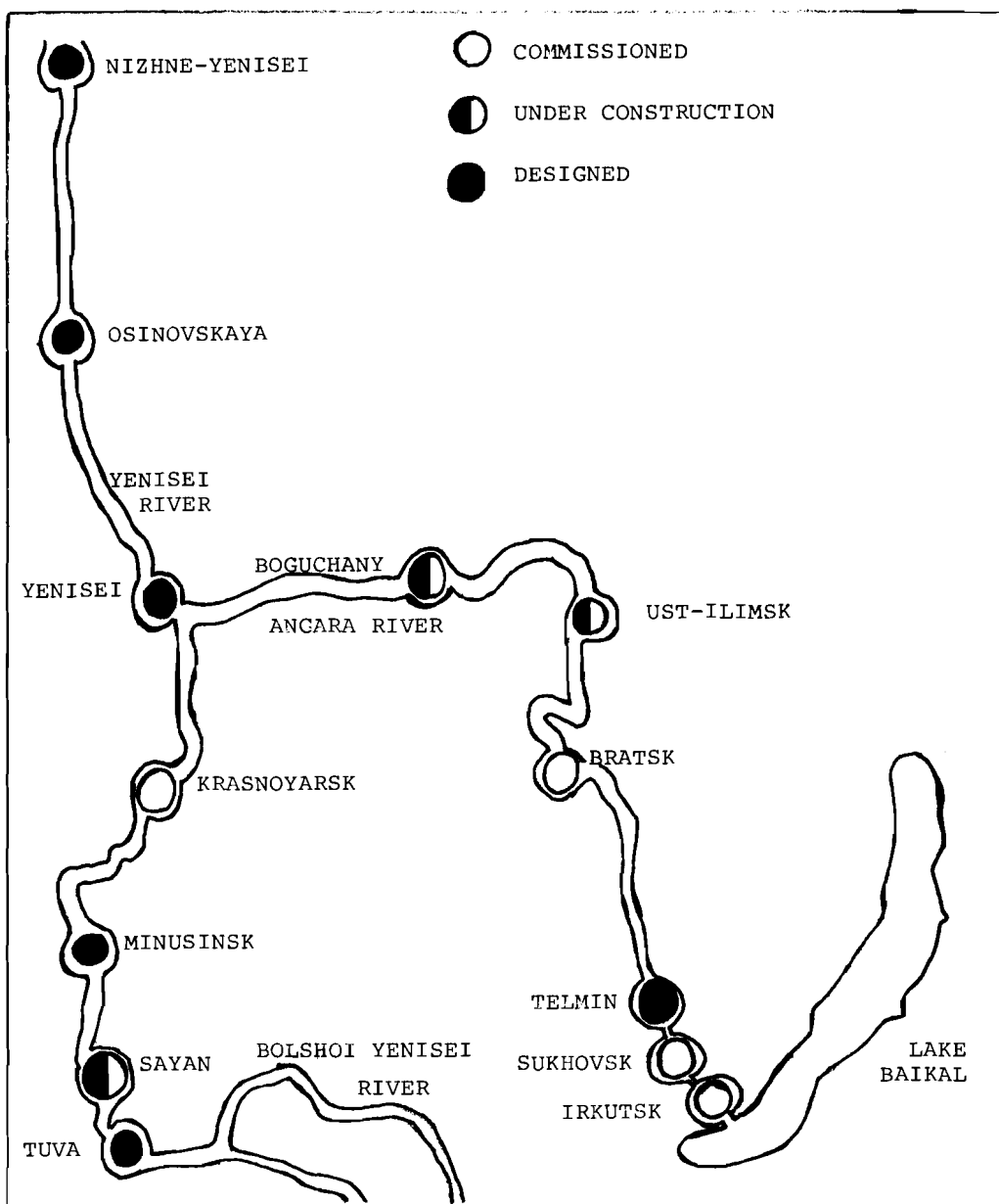


Figure 3. Cascade of hydroelectric stations on the Angara and Yenisei Rivers according to the 1953 scheme.

The water discharge in the Angara during the year changes little. The maximum water discharge at the river head exceeds the minimum only by 6 times. On the Dnieper, at the Dnieper HPS the difference is as high as 200 times, on the Kama and at the Kama HPS it is 100 times, and on the Volga and at the Lenin HPS it is 30-40 times. Great fluctuations in the discharge of these rivers, even with the aid of large reservoirs, do not ensure an even load on the hydro-units year round.

The geological conditions for constructing a HPS are especially favorable in the middle reaches of the Angara River, where it flows in a narrow valley cutting through hard rocks that can serve as a reliable foundation for high dams.

Gidroproekt investigations carried out in the middle reaches of the Angara River has substantiated the construction of the Bratsk and the Ust-Ilimsk HPSSs. The former has already been built; the latter is nearing completion and its first units have already begun to generate electric power. Thus, the hydropower resources of this Region will be utilized in full in the next few years.

There are many forests on the territory adjoining the middle reaches of the Angara River, up to 90 percent of the total area. The reserves of wood amount to $1.4 \times 10^9 \text{ m}^3$, with a total area of 7.8 million hectares under forests. The reserves of mature and overmature stands of the coniferous species reach 257.5 m^3 for pine; 242.1 m^3 for cedar, and 236.8 m^3 for larch per hectare. The quality of wood is high.

There are various mineral deposits in the Region. Iron ores are most important and valuable. There are the Angara-Ilimsk and the Angara-Katsk iron-ore deposits on the territory; these are black iron ores containing 30-40 percent of useful components. These resources are estimated at several thousand million tons. Currently, one deposit, the Korshunovo, has been developed; a quarry there has a capacity of 15 million tons of crude ore annually. Preparations are being made for working the Rudnogorsk deposit with an annual capacity of 5-7 million tons of crude ore. Geological reserves of iron ores in the Region are sufficient to satisfy the needs of a metallurgical plant.

Coal bearing fields have been discovered in the Region, and the coals there are of a high heat value, with a low sulphur content, and are thus a good energy producing fuel. Currently, the first deposits of industrial value are being explored.

A large deposit of quartzitic sand, Igirminsk, was discovered in the Region a few years ago. It will therefore be possible to build a quarry and a sand dressing plant for producing moulding sands.

Geological reserves of common salt suitable for working by using the underground leaching method are virtually unlimited;

it is possible to extract table salt and also raw materials for the chemical industry.

There are many local building material deposits in the Region: raw materials for making bricks and keramzit, building sands, sand-gravel mixture, building stone, and limestone. Some of these materials are being used for construction and engineering purposes.

The economic development of the Region contributes to a more intensive study of mineral resources, inasmuch as it facilitates prospecting work resulting from the construction of transport lines. Prospecting work over the past few years has shown the possible existence of oil and gas fields in the Mid-Angara Region. Vast reserves of high quality water and large-scale construction sites also contribute to the industrial development of the Region.

Good conditions for fishery have been created on big reservoirs in the middle reaches of the Angara. However, the possibilities for developing agriculture are limited because of the severe climatic conditions and relatively poor soils.

ECONOMIC DEVELOPMENT OF THE BITPC

The Mid-Angara Region was settled by Soviet explorers much earlier than the remaining part of the Irkutsk Region. In the late eighteenth Century, an advantageous transport and geographic situation and the possibilities for farming made it possible to turn the Ilimsk Region along the valley of the Angara into a base for the settling and exploration of other regions of Eastern Siberia and the Far East.

Because of difficult conditions of navigation down the Angara River (the swift current and numerous rapids and sandbanks), the Region became less important in the economy of Siberia once the Moscow cart transport road, which passed south of the Mid-Angara Region, was built.

The beginning of the industrial use of the territory's natural resources dates back to 1845, when on the bank of the Dolonovka River, not far from Bratsk, the construction was started of the Nikolayevsk iron foundry based on local iron ores and charcoal. In 1847, the plant started production, and construction was completed in 1850. Its maximum output was 200,000 poods (1 pood equals 36 pounds) of pig iron, and 150,000 poods of iron and castings. The Nikolayevsk iron foundry played a leading role in the economic development of Eastern Siberia. The plant has produced steamers for the Angara River and equipment for the Lena goldfields as well as rolled metal, sheet iron, stoves, etc. During the construction of the Trans-Siberian Railway line, the plant was commissioned to manufacture rails and bridge iron. The plant stopped work in 1899, when the western part of the

Baikal Region became connected by a railway with the European part of the country.

The construction of a cart transport road between Tulun and Bratsk, completed in 1897, brought a greater influx of settlers to the Mid-Angara Region, and contributed to the development of agriculture here.

During the 1930s and 1940s when the automobile fully replaced cart transport, large trans-shipping bases for supplying the northern parts of the Irkutsk Region and Yakutia were set up in the Mid-Angara Region. Cargoes were going down the Angara River to the pier of Zayarsk, from where they were delivered by lorries to Ust-Kut on the Lena River.

In 1949, a railway line connecting the Angara River bank with Taishet created favorable conditions for the development of the natural resources of the Mid-Angara Region.

The decision in 1954 to construct the Bratsk HPS greatly accelerated the development rate of the Region's natural resources, primarily, timber. While preparing the bed of a future reservoir for flooding, it was necessary to fell about 40 million m³ of wood on a territory of 370,000 hectares.

Inasmuch as the comprehensive development of the resources of the Mid-Angara Region was planned from the beginning, in September 1956 the USSR Council of Ministers decided, to organize a single base in Bratsk for constructing all projects in the region. In December 1955, Bratskles, a trust in charge of clearing the site of the future reservoir from forests, was set up. In a short period it organized 26 industrial forestry centers that were placed at even intervals on the territory of the future reservoir.

A sharp increase in timber procurement in the Mid-Angara Region required the construction of timber trans-shipping bases to transport timber floated down the Angara River and its tributaries to the railway. Wood sawing and processing plants were needed to improve the conditions of wood transportation and to meet the needs of local users of timber.

In 1957, the Moscow State Institute for Urban Planning completed a district plan for the Bratsk Power and Industrial Center, which took into account new engineering methods and techniques and the economic development level of adjoining territories (Figure 4). The essential changes concerned power supply, which before commissioning the HPS, was oriented toward the transmission of electric power from the Irkutsk-Cheremkhovo Territorial Production Complex, as well as the wood processing industry. (The all round use of wood and concentration of wood processing operations have increased.)

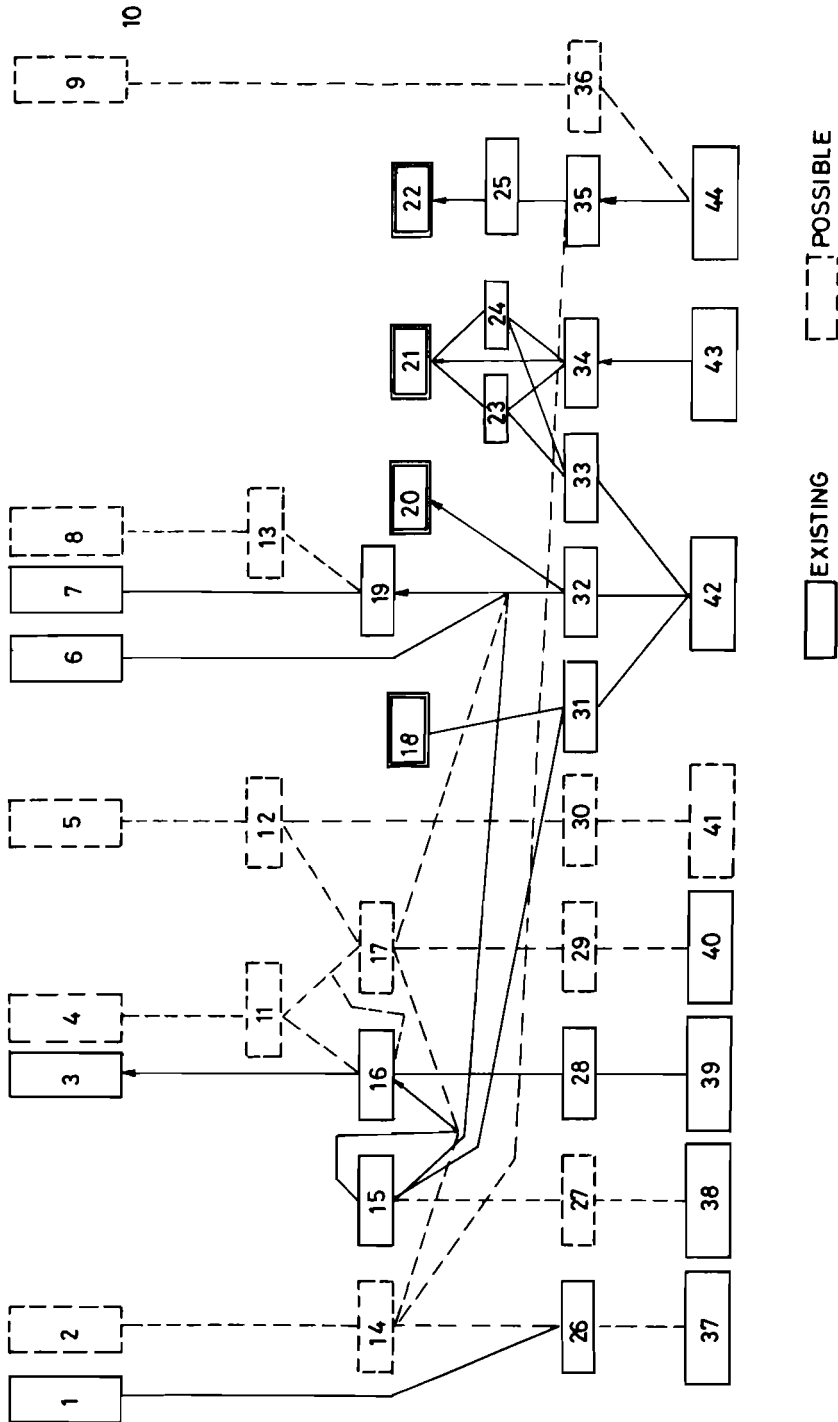


Figure 4. Technological connections for the use of resources in the BITPC, 1957.
(See next page for key.)

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|-----------------------------------|--------------------------------|
| 1. iron-ore concentrate; | 22. construction of industrial |
| 2. iron, steel; | and other facilities; |
| 3. cellulose, cardboard, lumber, | 23. storage; |
| plywood, etc.; | 24. processing; |
| 4. cellophane, synthetic fiber; | 25. production of local |
| 5. synthetic fiber, rubber, | building materials; |
| polyethylene, etc.; | 26. mining and dressing; |
| 6. electric power; | 27. mining and dressing; |
| 7. aluminium; | 28. timber logging; |
| 8. aluminium products; | 29. mining and treatment; |
| 9. moulding sand; | 30. production and refinement; |
| 10. TPC products consumed outside | 31. water supply; |
| TPCs bounds; | 32. electric power; |
| 11. production of cellophane and | 33. fish-farming; |
| synthetic fiber; | 34. agricultural production; |
| 12. organic chlorine synthesis; | 35. mining and dressing; |
| 13. processing of aluminium; | 36. mining and dressing of |
| 14. electrometallurgy; | moulding sands; |
| 15. thermal energy production; | 37. iron ore; |
| 16. thorough mechanical and | 38. coal; |
| chemical processing; | 39. forest resources; |
| 17. electrolysis of sodium | 40. common salt; |
| chloride; | 41. oil, gas; |
| 18. water supply system; | 42. water resources; |
| 19. electrolysis of alumina; | 43. arable land; |
| 20. power supply system; | 44. nonmetallic minerals. |
| 21. supplies to population; | |

In 1958, construction began of a large timber production complex in the Mid-Angara Region to process the wood procured in this area. Its annual capacity was 7 million m³ of wood. At the same time the Korshunovo iron-ore deposit was developed, and in 1961, an aluminium works was constructed.

From the beginning, the economic development of the Mid-Angara Region was carried out with a view to achieving utmost efficiency. The deadline for the filling of the reservoir was postponed, since the effect of curtailing expenses for cleaning the beds for future reservoirs proved to be considerably greater than the work of the HPS at higher water level marks. Delaying the filling of the reservoir for two years made it possible to curtail the capital expenditures on felling operations by 110 million roubles, the number of workers by 11,000, and the cost of 1.0 m³ of wood by 0.1 rouble. The maximum annual volume of felling was thus lowered by 3 million m³ [6].

The construction of the Bratsk HPS proceeded at a rapid pace. Work on the main structures began in 1957, and in 1959, the Angara River was spanned. In 1961, the first units were coming into operation and, in 1967, the station's capacity reached 4100 kW.

Buildings of the above-mentioned industrial enterprises, food industry enterprises and various components of the production and social infrastructure were being set up simultaneously with the construction of the Bratsk HPS. As the material base of construction strengthened, the rates of building were raised, thus making it possible to commission new capacities concurrently with the completion of the HPS. In 1965, the first installations were coming into operation at the Bratsk timber production complex and the Korshunovo ore-dressing plant, and in 1966, at the aluminium works. In 1963, the Bratsk dairy plant began operating, and in 1964, a meat packing plant became operational.

The reduction in the amount of work on the construction site of the Bratsk HPS after 1962 relieved machines, mechanisms, and equipment used in hydroengineering work. The demand for hydraulic engineers and manpower also diminished. All this made it possible to prepare for constructing the Ust-Ilimsk HPS which had to be built under difficult conditions. The site of the new station was 250 km from Bratsk, and was not connected to it by any overland transport lines. There was no shipping in this section of the Angara River owing to numerous rapids. All this required additional time and expenditures. At first, an automobile road was laid out on the left bank of the River. After the removal of rapids, the section from Bratsk to Ust-Ilimsk became navigable. In 1963, because transport arteries existed, it was possible to begin deliveries of machines and building materials necessary for constructing the station. To supply the construction site with electricity, power transmission lines were installed from the Bratsk station to Ust-Ilimsk. In 1966, the construction of the station began; in 1968, the Angara was begun, and the first units became operational in 1974 [7].

As in the previous case, the development of the adjoining territories had to be comprehensive; therefore by 1970, a railway line had been built from Khrebtovaya station to Ust-Ilimsk. This made it possible to considerably lower the cost both of delivering building materials and of shipping timber procured from the area of the future reservoir. In determining the rate of the construction of the HPS due account was given to the interests of all departments taking part in the development. Therefore, the time allotted for filling the reservoir was also extended beyond the limits dictated by the construction of the HPS.

The intensive industrial development of the Mid-Angara Region has had a profound influence on the development and distribution of agricultural production there. The creation of reservoirs at HPSSs has caused a shift of agricultural production from river valleys, where it used to develop, to watersheds with their less favorable natural conditions and lower soil fertility. This called for the use of greater amounts of fertilizer especially during the initial period. To fully and quickly satisfy the local requirements of the population for local food-stuffs, agricultural enterprises have been organized along with an expansion of traditional farming and livestock breeding, on an industrial basis --e.g., mechanized poultry farms, hothouses, fattening farms.

RESULTS OF THE DEVELOPMENT

The planned exploitation of the natural resources in the Mid-Angara Region, which began in the 1950s, laid the foundation for the creation of the BITPC. The role of the BITPC is noticeable not only in the economy of Eastern Siberia but also in the national economy.

During the two decades of intensive economic development, large industrial projects have been built here (Figure 5). The Bratsk aluminium works, once it reaches its design capacity in the next few years, will become the country's biggest electrolysis plant. In 1974, the first three units of the Ust-Ilimsk HPS were commissioned, and the construction of the Ust-Ilimsk timber production complex was begun. To develop timber resources in the BITPC, several dozen industrial forestry centers were organized. Agricultural production on new lands, developed after flooding old arable lands during the filling of the Bratsk reservoir, was started practically.

The territory of the BITPC comprises 11.5 percent of the Irkutsk Region; 15 percent of the Region's population lives here. Currently the BITPC accounts for 28 percent of the gross industrial output of the Region. In 1974, it produced 29.3×10^9 kWh of electricity; 6.2 million tons of iron-ore concentrate; 220,000 tons of commercial cellulose; 403,000 m³ of ferro-concrete items 8.7 million m³ of workable wood; 1.8 million m³ of lumber. In 1975, the share of the complex in the industrial output of the Irkutsk Region is expected to exceed 30 percent. Its role is especially important in such areas as ferrous and non-ferrous metallurgy, production of electric and thermal energy, building materials, timber and cellulose. In terms of size of industrial production, the BITPC plays a significant role in the Angara-Yenisei Region: its share in the Region's industrial output has already exceeded 10 percent. In this respect, the complex is second only to the older Central-Krasnoyarsk TPC and the Irkutsk-Cheremkhovo TPC [8].

To comprehend the results of the economic development of the BITPC, let us look at its changing role in the Region's economy. For example the BITPC's share in the Region's population grew from 3.3 percent in 1939 to 14.9 percent in 1970, and its contribution to the regional production of grain, potatoes, vegetables, meat, fowl and milk has recently increased [9].

The BITPC has powerful construction enterprises. In 1974, about 400 million roubles were used for construction and assembly work on the territory, more than 80 percent of which was used by Bratskgesstroi. The BITPC construction organizations have considerable capacities for producing building materials; in 1974, the total amount of building materials production exceeded 100 million roubles. Some of these materials satisfy in full

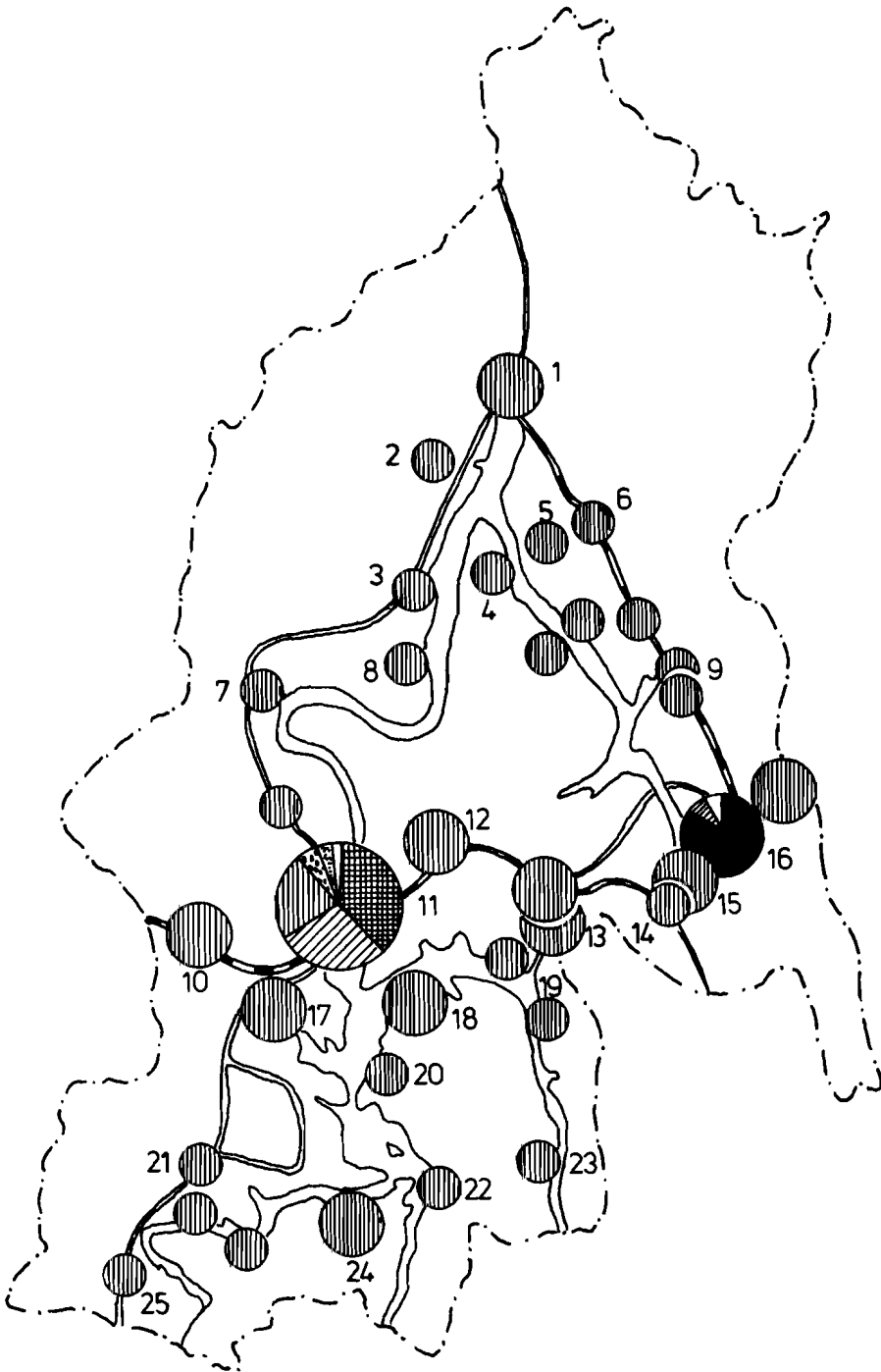
















Figure 5. Location of industrial production in BITPC as of January 1, 1975.
(See next page for key.)

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|--|---|-------------------------------|
| 1. Ust-Ilimsk; |  | timber, woodworking and |
| 2. Badarma; | | cellulose and paper |
| 3. Educhanka; | | industry; |
| 4. Dalini; |  | building materials industry; |
| 5. Kedrovi; |  | food industry; |
| 6. Tuba; |  | other industries; |
| 7. Sedanovo; | | |
| 8. Ershovo; |  | railways; |
| 9. Rudnogorsk; |  | motor roads; |
| 10. Turma; |  | boundaries of territorial- |
| 11. Bratsk; | | production complex; |
| 12. Kezhem; | | |
| 13. Vidim; | | |
| 14. Zatoplyaemaya; | | |
| 15. Shestakovo; | | |
| 16. Zheleznogorsk; | | |
| 17. Tarma; | | |
| 18. Narataj; | | |
| 19. Chistaya Polyana; | | |
| 20. Ozernij; | | |
| 21. Pokosnij; | | |
| 22. Tynkobi; | | |
| 23. Karakhun; |  | over 1×10^9 roubles; |
| 24. Kharanzhino; |  | from 50-100 million roubles; |
| 25. Ilir; |  | from 5-15 million roubles; |
|  power industry; |  | less than 5 million roubles. |
|  ferrous metallurgy; | | |
|  nonferrous metallurgy; | | |

the construction requirements on the BITPC territory; moreover, they are shipped for use in other regions of the country and are also exported.

The organization of large enterprises in the BITPC has changed the role and significance of this Region in Siberia. Due to the transmission of great amounts of cheap electricity and the supply of building materials to outside users, the BITPC contributes to the development of other regions of Siberia.

Many enterprises in the country use products manufactured by plants and factories of the BITPC. Currently, millions of cubic meters of wood, hundreds of thousands of tons of lumber, several hundred thousands of tons of cellulose and cardboard, and over 6 million tons of iron-ore concentrate are shipped from here; some is exported.

Industrial enterprises in the BITPC, both those that are operational and under construction, are characterized by high

economic efficiency. During the first three years of the current Five-Year Plan period, they yielded 923 million roubles in profit. The Bratsk HPS has paid for itself several times over. The profitableness of producing iron-ore concentrate at the Korshunovo ore-dressing plant exceeds 40 percent. In the first three years of the ninth Five-Year Plan, it turned a profit of 61 million roubles. The Bratsk timber production complex is the country's largest in terms of commercial output and profit, yielding an annual profit of about 50 million roubles. The wood procured by the BITPC enterprises is distinguished by its low cost and high quality.

The development of the natural resources in the Mid-Angara Region has led to considerable changes in the living conditions of the population. In place of small villages, modern settlements and towns have sprung up, and urban housing facilities has been fully modernized.

Essential changes have occurred in the transport area. Before the development of this territory, there were practically no overland transport lines and horse-driven carts were the main means of transportation; now by contrast, the industrial centers of the complex are connected by railway lines. Motor roads have been laid out to all centers of agricultural production and the timber industry. Air transport has also developed intensively. Airplanes now fly to all remote populated areas. An airfield has been built in Bratsk, capable of receiving large airplanes. Because of deep reservoirs and economic development, water transport has become advanced; it carries large cargoes of timber and building materials.

As a result of the large amount of cheap electricity, it is possible to economically use it in industry, for transport, agriculture and construction and also for daily living activities. The majority of homes in the area have electric stoves, refrigerators, washing machines, vacuum cleaners, etc. Electric power is also used for heating. For example, in the town of Ust-Ilimsk, the supply of heat is regulated by electric boiler-rooms. The population of the BITPC lives in modern comfortable cities and settlements. Considerable changes have also taken place in the field of culture. Bratsk has a branch of the Irkutsk Polytechnical Institute for training skilled personnel for the BITPC and adjacent regions. There are secondary educational establishments and vocational schools. Both central and local telecasts can be received throughout the entire territory of the BITPC. Considerable advances have also been made in creating facilities for rest, recreation, and sport.

The development of the BITPC in a poorly inhabited inclement region will be studied with interest for a long time to come as an example of the implementation of a comprehensive program.

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Discussion

The discussion opened with an inquiry about the role of the territorial production complex (TPC) in regional development. It was pointed out that the development of a TPC is a process involving sectorial and regional problems. Considerable efforts have been made to improve the allocation of productive forces to support regional development; this is supported by the planning process. More than 100 research institutions are involved in the development of master schemes and the national plan.

Attention then focused on the relationship of the Ministries in charge of industrial development and the local Soviets. It was noted that decisions have been taken to enhance the role of the local Soviets. The formation of the City Soviet in Bratsk was a first step toward the supervision and support of the activities of enterprises located there. The local Soviets play a major role in assisting enterprises to formulate and implement their development plans.

Responding to a request for information about the planning process in the USSR, one participant stated that during recent years, intensive work has been carried out on the fifteen-year development plan for the period 1975-1990. The plan is comprehensive, and takes into account technological and scientific trends. The 25th Congress of the Communist Party of the Soviet Union has instructed that work continue on the plan, which will be modified every five years. Moreover, the five-year plan will be updated annually. Significant changes occurring during the five-year period will be incorporated into the plan by government decrees. Another mechanism for updating the plan is annual indicators.

Alternatives to the approved plans are considered at the pre-planning stage. In the case of the Bratsk-Ilinsk Complex, thirty years ago there were many who opposed its development; they thought it more feasible to develop the areas around the trans-Siberian railroad. However, it was soon recognized that it was more important to integrate the development of areas rich in natural resources. Similar discussions took place at the initial development stage of the Complex, when many considered it more practical to export the region's energy to other areas of the Soviet Union. Discussions regarding the nature of further developments of the Complex still take place, as for example the recent talks about developing the chemical industry at the Complex.

During the preplanning stage, research and design are carried out by the appropriate institutions and organizations, and suggestions are made to the responsible planning organization. Information essential to the planning process is also received from the Ministries and Republic authorities. The process is completed when the plan is approved by the Supreme Soviet. The views of

each hierarchical level are considered, and decisions are taken that seek to accomodate all interests.

The management system for the BITPC was another subject of discussion. It was pointed out that the problems of the development of the BITPC are the responsibility of the Board of Directors of the Complex, headed by the Directors of Bratskgesstroi, in conjunction with the managers of the local enterprises.

There is no overall management organization responsible for all TPCs in the Soviet Union, although the economic system supports the possibility of such a development. The 25th Congress of the Communist Party of the Soviet Union recommended that this problem be studied in detail.

PLANNING, MANAGEMENT, AND ORGANIZATION

The Role of Republic and Local Planning and
Management Bodies in the Development of the BITPC

N.A. Soloviev and K.Ya. Donchenko

INTRODUCTION

The Directives of the 24th Congress of the Soviet Communist Party set the task of a further improvement of the distribution of productive forces, a comprehensive development and specialization of the economy of the Soviet Republics and economic regions, and a properly balanced combination of territorial planning with the branch principle of national economic management. Great importance is attached to the comprehensive territorial planning for managing the various administrative subdivisions, including territorial production complexes (TPCs).

In the first years of Soviet power, planners were faced with the problem of coordinating all branches of the national economy with respect to a particular territory. The need for such an approach was emphasized by V.I. Lenin who pointed to the significance of "the model organization of a 'complex' even if on a small scale. I say complex, meaning not just one farm, one branch of industry, or one factory, but a totality of economic relations, a totality of economic exchange, even if only in a small locality" [1].

The concept of the TPC was outlined in 1920 in the national electrification plan Goelro, elaborated by the State Commission for the Electrification of the USSR and also in the proceedings of the State Planning Committee on economic zoning (1921-1923). These documents provided methodological guidelines for the Soviet economic zoning policy aimed at outlining and substantiating territorial production complexes of different rank.

N.N. Kolosovsky, I.G. Alexandrov, and other Soviet scientists attached paramount importance to the formation of TPCs over the vast territory of the country. They believed that such complexes would provide for the optimal use of natural resources in their most advantageous combinations, ensure coordination of production processes and the rational division of labor, offer flexibility in the use of raw materials, energy, means of transport, and manpower, and allow for the establishment of the social and industrial infrastructure.

The early five-year plans included detailed territorial sections that contained indices for economic regions. Most of the territorial reports contained sections on economic complexes. At this time, the basis for the territorial division of labor was

laid down, and the specialized Urals-Kuznetsk and Dnieper TPCs were taking shape; in addition, the structure was worked out for future complexes such as the Angara complex which is a primary link in the Irkutsk-Cheremkhovo TPCs.

The Directives of the 24th Congress of the CPSU and the Five-Year Economic Development Plan of the USSR for 1971-1975 [2] have stressed the advisability of the rapid economic development of a number of TPCs including the Kuzbas, the Krasnoyarsk-Achinsk, the Sayansk, and the Bratsk-Ilimsk. Comprehensive plans are being worked out for developing and distributing the productive forces of not only the Union republics and economic areas, but also the individual territories, regions, autonomous republics, and TPCs. These plans provide for direct outlays for industrial construction and development of general engineering communications, and contain estimates of possible savings from group distribution of production sectors. This is not sufficient, however, for an overall assessment of the efficiency of the development of the enterprises. Solutions have to be found to problems of optimal dimensions of the nonproductive sphere which is needed for the normal operation of the TPC. Account should also be taken of the cost of constructing transport systems and of the rapid growth of agricultural production needed to meet the population's demand for foodstuffs.

Republic and local planning bodies play an increasingly important role in setting up TPCs. A network of territorial design organizations has been set up for regional design work in connection with the development of TPCs.

Principles have been worked out in the USSR for planning industrial centers. Formation principles have been determined; rules have been established for planning and financing the construction of central projects; norms and recommendations exist for drawing up schemes of master plans for increasing the efficiency of capital investments in industrial construction, for solving city planning problems, such as building new towns and for reconstructing established urban communities.

The current level of development of the productive forces is characterized by a number of features including the increasing role of Siberia and the Far Eastern part of the country in the national economy. TPCs of different sizes and structures should become the main form of spatial organization of production in this vast area. Selective use of resources in the country's eastern areas, among them East Siberia, has proved effective, and there are grounds for supposing that this form of spatial organization will continue to exist for a long time.

The territorial organization of production in East Siberia in the form of TPCs is an advanced form of spatial organization of the national economy, ensuring an increase in labor productivity and a saving of up to 10 to 20 percent of the total construction costs for individual regions (in northern and

mountainous areas up to 5 percent). Group planning for construction also leads to reduced operating expenses, lower manpower requirements and more built-up areas, and protects valuable farm land. For example, the organization of only a few industrial centers, i.e., Irkutsk, Ziminsk, Chunsk, the northern stretch of Ust-Ilimsk, resulted in savings of about 74 million roubles for construction cost and 12 million roubles for operating expenses.

Creating TPCs in new developing areas involves considerable investments of capital and time. In the long run, these complexes should be economic, thus justifying their existence. Specialized major TPCs have ample funds and energy resources, which account for their high labor productivity and the low cost of their products.

Organization of TPCs in East Siberia is greatly influenced by specific Siberian factors, e.g., vast territory, uneven economic development, sparse population, and great diversity of natural conditions and resources.

CHARACTERISTICS OF EAST SIBERIA

East Siberia accounts for 43 percent of the aggregate energy potential of the USSR. Geological reserves of coals reach 4×10^{12} tons i.e., 45 percent of the country's total resources. Particularly important is the Kansk-Achinsk brown coal basin where coal mining is more economical than in the Kuznetsk coal basin. Unit capital investments per ton of comparative fuel and the cost of mining a ton of coal in the Kansk-Achinsk basin are 25 to 33 percent less than in Kuzbas. The prospected coal reserves of the Kansk-Achinsk will permit an annual output of coal of up to 1×10^9 tons a year. The Minusinsk, Irkutsk, Zabaikalsky, and other coal fields in East Siberia will be able to meet the bulk of the region's demand for industrial fuel.

Economically efficient hydropower resources of the Angara-Yenisei basin exceed 50 million kW, which is equivalent to a potential annual electricity output of 250 to 290×10^9 kWh. Moreover, as compared to the Volga-Kama cascade, the average unit outlay for the Region's power stations cascade, is twice as much, and the cost price of one kWh is 25 percent less.

The concept of East Siberia's oil and gas resources is changing. The Angara-Yenisei Region is now regarded as a new oil- and gas-bearing province in the USSR. Commercial oil and gas deposits will be found and developed here.

Large reserves of nonferrous, rare, and precious metals have been discovered in East Siberia such as deposits of readily dressed magnetite iron ores in the Angara-Ilimsk, the Mid- and the Lower-Angara, and Sayany areas; it is expected that the

development of these resources will meet the demands of a metallurgical plant being constructed in Taishet.

East Siberia possesses large resources of fluor spar, graphite, talc, mica, asbestos, magnesite, and practically unlimited resources of rock salt and raw materials for the construction industry.

The Region's forest stock exceeds $27 \times 10^9 \text{ m}^3$, i.e., 37 percent of the total national forest resources, the bulk of the forest stock being accounted for by mature and overmature coniferous species. The exploitation of forest resources in East Siberia's most promising timber industry zone involves less expenditure than in other regions of the country.

The development of natural resources in many areas of East Siberia appears to be economically feasible in spite of the cost-increasing effect of the severe natural-climatic conditions, rugged terrain, and high seismicity of the territory. This is borne out by the estimates of design organizations, and also by good economic indicators of numerous operating enterprises.

The large-scale development of the natural resources in East Siberia opens up tremendous prospects for economic progress. Construction of major power engineering enterprises within TPCs, the expansion of nonferrous and ferrous metal ore mining and of the mining of other mineral resources, and the intensive development of forest resources will form a powerful basis for expanding the Region's productive forces and also strengthen the entire country's raw material base.

For new economic development, ways should be sought to reduce outlays for capital construction, and to ensure maximum efficiency in the operation of manufacturing enterprises and in the nonproductive sphere by improving the territorial organization of production, in accord with departmental principles of economic management. The increase in the efficiency of national production will be closely linked to the formation of TPCs, such as the BITPC.

BACKGROUND AND CHARACTERISTICS OF THE BITPC

The formation of the BITPC began in 1954 with the setting up of Bratskgesstroi. This organization has played a major role in the construction of numerous enterprises in the Mid-Angara zone, mostly in the Bratsk administrative district. Work carried out there involved building motor roads, power transmission and communication lines and laying a foundation for the construction of cofferdams for the right bank excavation of the Bratsk hydropower station (HPS).

In addition to the construction of the HPS, the Bratskgesstroi built enterprises for a timber industry complex, the

Korshunovo mining and ore-dressing mill, an aluminium works, and other projects ordered by a number of ministries and departments; it also executed forest removing operations at the bed of the future storage lake.

Thus the creation of the BITPC provided for a centralized management body that assumed additional financial responsibility in the pioneering stage of the development of the complex.

Currently, there is a new management body, the Board of Directors, that is vested with wide powers and functions in the territory of the BITPC. This body discusses and solves problems related to the development of the productive forces at the complex on the basis of proportional participation of the ministries and departments concerned.

The Board of Directors supervises the construction of enterprises of the social infrastructure over the territory comprising the Bratsk, the Ust-Ilimsk, and the Nizhneilimsk administrative districts. The Board of Directors establishes contacts with republic and local planning organizations, as well as with economic, Soviet, and Party organizations. In cooperation with republic and local planning bodies, it works out annual, five-year, and long-term plans for developing the productive forces. This ensures a more rational location of industrial enterprises with a view to a more effective use of natural and human resources, and a comprehensive development of the economy with regard to the advanced organization principles for industry, construction, and agriculture.

The BITPC has two industrial centers, Bratsk and Ust-Ilimsk and a mining industry center, Zheleznogorsk. There are four towns (Bratsk, Ust-Ilimsk, Vikhorevka, and Zheleznogorsk-Ilimsk) and seven urban communities, with a total population of 400,000.

In 1972, the BITPC produced over 24×10^9 kWh of electricity, 3.6 million kcal of thermal energy, over 5 million tons of iron-ore concentrate, and 168 thousand tons of commercial cellulose [3].

Operating within the BITPC are major industrial projects, such as the Bratsk HPS (4.5 million kW), the Korshunovo mining and ore-dressing combine, the Bratsk timber industry complex, a construction equipment plant, and a large aluminium works; the first power generating units of the Ust-Ilimsk HPS are being completed, and work has begun on constructing the Ust-Ilimsk timber industry complex.

The new lands reclaimed to account for the loss of lands flooded by the Bratsk storage lake are now the site of agricultural production developments.

The complex's enterprises now in operation or under construction are characterized by high economic efficiency: the

Bratsk HPS generates the country's cheapest electricity (0.035 kopeks/kWh); the costs of the iron-ore concentrate, aluminium, and timber industry products are below the national average.

The main reasons for developing the BITPC are cheap hydro-electric power of the Bratsk and Ust-Ilimsk HPSSs, high concentration of commercial deposits of iron-ore with a high iron content, ample reserves of raw materials, and large land and water resources.

The territory of the BITPC is characterized by dense afforestation; the total timber reserves are $1.4 \times 10^9 \text{ m}^3$. The excellent technical and economic characteristics of the forest tracts result in a relatively low cost of lumbering and high quality timber.

The accelerated development of the productive forces of the BITPC is facilitated by the availability of a powerful construction industry. The intensive economic development of the complex is linked to the operation of the western section of the Baikal-Amur Railway (Taishet-Bratsk-Ust-Kut), a large part of which runs across the territory of the complex. The construction of the Railway's central and eastern sections make it possible to locate at the complex enterprises of the processing industry.

The current sectorial structure of industry is characterized by a relatively high share of specialized branches which account for about 93 percent of the gross industrial output and about 98 percent of the industrial-production assets.

In the future, aluminium production will be expanded within the BITPC, and an oil pipeline is expected to be laid toward the head stretch of the Baikal-Amur Railway (from the Sibirsky oil main). The favorable conditions for prospecting gas and oil deposits, and the availability of vast rock salt resources (in the Angara-Lena salt-bearing district) will enable the development of chemical and petrochemical industries in this region, thus providing oil products, fuels, and lubricants for the northern areas.

Because of the positive electric power engineering factor, it is possible to consider building enterprises for processing the copper ores of Udokan.

Agricultural production at the BITPC has not yet reached a sufficiently high development level.

To meet the demands of the TPCs population for fresh foodstuffs, it is advisable to set up a broader network of hotbed and greenhouse farming facilities, as well as modern cattle-breeding complexes.

Within the BITPC it is possible to organize large-scale production of vegetables and potatoes, using hot waters from

thermal power stations and cheap electricity for heating glass-covered ground. Owing to the high hydroelectric power capacities available at the complex, there is also a possibility of heating some of the open ground planted with potatoes and other vegetables.

The transport development level of the BITPC, (for Siberia's conditions) is high. Running across the complex's territory are the Taishet-Lena and Khrebtovaya-Ust-Ilimsk Railways; a network of motor roads has been built to link the agricultural enterprises and forestry farms with the district centers - the town of Bratsk, Ust-Ilimsk, etc. Air transport is becoming important as are water transport on the Angara and on the water reservoirs of the Bratsk and the Ust-Ilimsk.

Republic and local planning and management bodies play a major role in the construction of housing and public utility facilities and in other activities aimed at raising the living standards.

The city of Bratsk is a good example of the major social-economic transformations taking place in the northern zone of the USSR. Bratsk is one of the major industrial centers of Siberia with a high scientific-technical level of production, and highly skilled manpower. It is becoming a well-organized center of culture. There is a branch of the Irkutsk Polytechnical Institute, a network of secondary technical schools, special schools (pre-school education, medicine, music), as well as urban and rural vocational-technical schools. Over 25,000 children study at general education schools. A network of pre-school childcare institutions has been set up for about 12,000 children, a hospital complex with over 1500 beds, a cinema, clubs, museums, libraries, sports arenas, and a television center have been built in Bratsk. A recreation zone has been built on the shores of the Bratsk sea for workers at the complex.

The further economic development of the complex is influenced by the following factors:

- The availability of a high-capacity power-engineering base that favors locating the major energy-consuming branches of the nonferrous metallurgical and chemical industries, and the total satisfaction of the electricity requirements of the industrial, construction, transport, agricultural, and public utility enterprises. The total electricity consumption by the entire economy of the complex in the tenth Five-Year Plan period will amount to $21-22 \times 10^9$ kWh.
- The creation of specialized capacities for processing wood resources through the use of lumber, woodworking, and wood-chemistry wastes.

- The development of branches that provide jobs for second and third family members (e.g., certain mechanical engineering and food industry branches that turn out nontransportable products).
- The accelerated development of highly effective deposits of iron ore and moulding sands.
- The expansion of geologic prospecting and exploration work to reveal commercial deposits of oil, gas, coal, chemical raw materials, etc.
- The further development of agriculture to a level that meets the requirements of the growing population for basic foodstuffs.
- The raising of the living standard of the local population to attract manpower from other areas of the country.

The economic development of the BITPC will be accompanied by the further improvement of its management organization and planning methods, the enhancement of economic incentives, and the creation of favorable conditions for a more rational use of capital investments, human and material resources.

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Prospective Links Between the BITPC and the Regions
Of the Northern Part of East Siberia

G.L. Tarasov

Under socialism the operation of the economic law of balanced development creates conditions for a purposeful geographical distribution and rational territorial organization of the economy to serve the interests of society. One important task of economic development in the USSR is to involve in the economic turnover the natural resources of the poorly developed regions, including those in the northern part of Siberia and the Far East. These regions are rich in natural resources, in particular, in various kinds of mineral raw materials, timber, water power and water resources. Use of the rich natural resources of the northern regions will help to provide the national economy with major raw materials and energy.

Bringing the natural resources into the economic turnover and a related intensive development of the economy of the northern territories will involve considerable investments of time and money. Solutions to the problems of developing these resources and of economically developing these regions must take into account the economy's demand for resources and the actual feasibility of specific programs for developing new areas.

One such stage entered upon in the 1950s was the development of the natural resources of the Bratsk-Ilimsk district in the Irkutsk Region and the formation of the Bratsk-Ilimsk Territorial Production Complex (BITPC). The historical development of the BITPC has been discussed in detail elsewhere in this volume.* While much work remains before the BITPC is completely developed, it appears worthwhile to use the existing facilities to help carry out development programs for the neighboring northern regions of East Siberia.

DEVELOPMENT OF THE NORTHERN REGIONS OF EAST SIBERIA

The initial stage in the development of these northern regions includes setting up powerful industrial bases in the Krasnoyarsk-Angara area and along the Baikal-Amur Railway (BAR). To establish the Lower-Angara complex in the Krasnoyarsk-Angara area, it is advisable to bring the area's plentiful water power, timber

*See N.A. Soloviev and K.Ya. Donchenko, *The Role of Republic and Local Planning and Management Bodies in the Development of the BITPC*.

and mineral resources into the economic turnover. The water power resources can be utilized by building two powerful hydro-power stations (HPSSs): the Boguchany station and the Middle-Yenisei station--with a combined annual output of about 50×10^9 kWh. The first order of priority is the Boguchany project, and work is expected to begin on a large scale in the near future. A prerequisite for constructing the Middle-Yenisei station is the working out of a technical scheme that takes account of the need to exploit the Gorevsk lead and zinc deposits.

The vast timber and mineral resources of the Krasnoyarsk-Angara area make it one of the richest regions of East Siberia. The development of these natural resources will result in the establishment of a large territorial-industrial complex with industries concentrated in two industrial zones: the Boguchany zone in the East, and the Lesosibirsk zone in the West. The economy of the Boguchany zone will be built around the production of hydroelectric power (another powerful HPS is envisaged on the Angara-Yenisei River), and of timber and wood-processing industries. In addition, a concentrating mill for processing the ore of the Tagarsk iron-ore deposit may be built.

In the Lesosibirsk zone, saw timber production is well developed, and future plans include supplementing it with the chemical processing of wood for optimal utilization. The specialization of this zone may also depend on such branches of industry as hydroelectric power generation (the Middle-Yenisei station) and mining (lead and zinc ore and iron ore).

As the Lower-Angara complex takes form and the industrial and nonindustrial infrastructure is developed there, conditions will arise for setting up power-consuming industries.

There is a plan for constructing the BAR and for developing the productive forces in the areas spanned by the railway. The program is comparable in size and importance to the large-scale programs for developing the oil and gas reserves in the West Siberian Lowland and for establishing a powerful energy-producing complex and energy-consuming industries in the Angara-Yenisei Region. The BAR is economically important because it will provide transport needed for developing the vast areas immediately adjoining the railway and those of Siberia and the Far East.

Extending the transportation links in the latitudinal direction will create more favorable conditions for the territorial division of labor, and will help to establish highly efficient industries in the areas under discussion. Besides, the construction of the BAR and the development of the economy in the areas through which it passes will give added impetus to the economic expansion of the southern parts of Siberia and the Far East. Several criteria are needed--for example certain allied production facilities are needed for providing the BAR area with building materials, foods, etc.

The economic importance of the Railway is particularly great since it provides favorable conditions for developing the enormous natural potential of the vast northern territories of East Siberia and the Far East.

Although the development plans for the productive forces in the BAR area have not been detailed and substantiated, it is possible to plan the development of a number of territorial-industrial complexes there, including the Upper-Lena, North-Buryat, Udokan, South-Yakut, Tynda, Urgal, and the Komsomolsk complexes. The closest links are most likely to be formed between the BITPC and those complexes in the BAR area which lie in its western part on the territory of East Siberia. In view of this it seems appropriate to give a brief description of the possible courses of their development.

The Upper-Lena complex is being formed in the Irkutsk Region, in the basin of the upper reaches of the Lena and its tributary, the Kirenga. The complex is being developed to exploit large resources of high quality timber. The total reserves of timber amount to about $2 \times 10^9 \text{ m}^3$ of predominantly valuable softwoods, including pine. It is expedient to build up a few timber complexes there that will include enterprises for deep mechanical and chemical processing of timber and the production of paper pulp. One such complex will probably be located alongside the BAR, near the village of Kazachinsky.

Moreover, the territory of the Upper-Lena complex appears to be rich in oil and gas. So far a few small oil and gas fields have been found there, but there is evidence that oil and gas will be discovered in commercial quantities in which instance oil and gas extraction will also become a basic industry of this region. Also, commercial reserves of common salt deposits may be found within the territory of the Upper-Lena complex. Thus conditions are present for the future development of a chemical industry for producing chloro-containing compounds, for example.

While developing the leading industries that form the core of the complex, it is necessary also to develop the allied branches of economy in the right directions and on an appropriate scale, especially in view of prospective economic links with other parts of East Siberia, including the BITPC.

The dominant industry of the Mamo-Bodaibo complex, located in the northeastern part of the Irkutsk region, is mining of gold and mica. The complex lags behind other areas in developing the infrastructure and in solving social and economic problems, largely owing to transportation difficulties. Communication with other regions is maintained either by seasonal river transport or by air. As answers are found to the problems of transportation the economic performance of the enterprises of the complex will improve.

Conditions for developing the productive forces in the northern part of the Buryat Autonomous Soviet Socialist Republic are good owing mostly to the availability of valuable mineral resources. The better explored resources include the Molodezhny deposit of chrysotile asbestos, and the Kholodninsk deposit of lead and zinc. Besides, evidence of deposits of many other minerals have been found, including nickel, aluminium ore, and manganese.

Furthermore, the northern part of the Buryat Republic is rich in timber, water power and water resources. The favorable conditions in the mountain valleys, particularly in the Muya Valley, make it possible to develop agriculture which will expand the local production of food. These natural resources will provide the basis for two industrial zones: the North Baikal zone and the Muya zone. Their development may be considered within the framework of a single North-Buryat territorial and industrial complex; nevertheless it should be remembered that the North Baikal zone has its own special regional conditions as it is situated within the conservation area of Lake Baikal. For this reason construction of enterprises severely affecting the environment must be restricted, and those that are created must comply strictly with environmental protection regulations.

The building up of the North Baikal zone will result from the development of the mining industry, the construction of enterprises needed for the operation of the BAR, and the use of the specific natural conditions to provide vacation facilities, the latter being best suited to meeting the requirements of a conservation area.

The development of the Muya industrial zone is based on the exploitation of mineral resources, particularly the Molodezhny deposit of chrysotile asbestos, and the water power resources of the Vitim River on which the Mokskaya hydroelectric station, with an output of 1.5 million kW, may be built near the BAR route. Besides, the adjoining regions have great reserves of timber thus allowing for the development of a large timber complex that will include enterprises for deep mechanical and chemical processing of wood.

The construction of the Mokskaya hydropower station (HPS) will not only ensure power supply to the northern parts of the Transbaikalian Region but will also solve problems connected with land improvement in the Muya valley. This will create more favorable conditions for setting up food producing enterprises specializing in produce that is difficult to transport, e.g. fresh meat and dairy products, vegetables, and potatoes.

Plans for the development of the northern part of the Chita Region include the establishment of the Udokan complex to make use of a large copper deposit. Other minerals are expected to be found there, so the tendency of that complex to specialize in mining may grow stronger. In view of the adverse natural

conditions of the region (a severe climate, high seismic activity, permanently frozen ground), metallurgical works for processing Udokan ores should be built farther south. Some of the service industries may also have to be located farther south for the same reasons.

Relationship of the BITPC to the Development of Other Complexes

The basic trends in the development of the productive forces in the near north of East Siberia determine the prospective relations of the BITPC and the complexes that will eventually appear in this section of East Siberia.

To adequately discuss these, it is necessary first to examine the experience gained in the process of building up the BITPC; this will help us to more efficiently form new territorial-industrial complexes and to avoid past mistakes.

Economic links between the BITPC and other regions of the near north will be developed. At the initial stage mostly one-way links will prevail in the form of assistance rendered by the BITPC in solving the problems of developing the productive forces in those regions.

Assistance in the following areas is considered: in carrying out construction work; in ensuring power supply; in furnishing other supplies; in carrying out research and design work; and in the training of personnel.

In the process of establishing the BITPC, a large-scale building industry was developed. It comprises not only construction units, but also enterprises manufacturing various kinds of building materials, e.g., large enterprises turning out reinforced concrete materials, ready-mix concrete, and plumbing and electrical fittings. The possibility therefore arises to directly use the capacities of this building industry to carry out construction in other regions. This can be done in principle by transferring some of the capacities and by supplying various building structures and materials.

However, these possibilities are in some measure limited, mainly because of the need to carry out much work within the BITPC itself, especially at the initial stage when a number of major projects will be under construction. Therefore, a study is needed to determine the scope and the areas of such assistance.

Considering the geographic proximity of the Boguchany and the Ust-Ilimsk zones and the kindred nature of their economies, it seems expedient to use the capacities of the building enterprises of the Bratskgesstroi to carry out construction work in the Boguchany zone. This is particularly true of the specialized capacities designed for building HPSSs. As the Ust-Ilimsk HPS is nearing completion, these capacities can be transferred to the

Boguchany HPS. It is likely that the capacities of the Bratsk-Ilimsk building industry may eventually be used to construct some other projects on the territory of the Lower-Angara complex (e.g., the timber and mining industries). However, the construction work on similar enterprises will get under way at the same time in some other regions of the near north of East Siberia, in particular in the western part of the BAR area. Definite construction schedules, types of enterprises, and other factors will have to be taken into account in order to determine the kind of assistance that will prove most effective. It appears that free capacities should be used first to render assistance in the construction of projects on the territory of the Upper-Lena complex.

Bratsk is one of the most suitable sites for setting up facilities for manufacturing special building structures used in the construction in the North. When considering this question, the needs of the BAR area will also have to be taken into consideration.

It is expedient that the BITPC should supply electric power to some parts of the near north. In particular, it is from there that electric power should be supplied to the western part of the BAR area at the initial stage of its economic development. For this purpose a power transmission line will have to be built along the BAR, with new industrial centers connected to it. However, the problems of supplying power to the BAR area, including its western part, will require a special solution at a later stage. This is because of the great increase in power loads, especially in the northern part of the Transbaikal Region, that will result from the establishment of large mining enterprises there. The loads will increase still further in the future if the railway is electrified. Thus consideration should be given to the problem of providing the northern part of the Transbaikal Region with its own large source of electric power; the Mokskaya HPS may eventually be this source.

Apart from this, even if there is a power transmission line from the BITPC, thermal power stations will have to be built in the industrial centers of the western part of the BAR area in view of the prospective thermal loads.

In addition to building materials and electric power, the BITPC can provide the other regions of the near north with other supplies, although the range is relatively small because of the narrow economic structure of the complex. In particular, the establishment within the complex of a machine building and metal-working industry will help provide those regions with certain types of machines and equipment. Currently we can be certain of only the availability of future supplies of heating equipment, which will be manufactured at a factory now being built in Bratsk. The specializations of the factory should consider the requirements of the BAR area.

As yet no plans have been drawn up as to the trends, scale, and target dates of the development of machine building in the BITPC. Economic conditions for its development there are not as good as for the regions lying farther south. However, if machine-building enterprises are located there, their specialization must take account of the needs of the near north regions. Specifically, Bratsk has certain conditions for setting up the manufacture of machines and equipment for the timber industry, for which there will be a great demand owing to the establishment of territorial-industrial complexes in the Krasnoyarsk-Angara Region and in the BAR area.

The repair facilities of the BITPC appear to be sufficient for meeting some of the needs of the near north regions under development, e.g., repairs of certain types of construction and timber machinery, motor cars and lorries, and, possibly, mining equipment.

We can also count on some surplus goods produced by other branches of the economy of the BITPC, but the quantities involved are as a rule small, since most of these branches play only an auxiliary role and are developed mainly to satisfy local needs. (This applies in particular to agriculture, light industries and the food industry.) Yet in some cases it may prove feasible to furnish certain types of goods manufactured by those branches to other regions.

The rapid development of the BITPC, and the creation of a sufficiently powerful and adequate infrastructure there will provide more favorable conditions for training skilled personnel and for carrying out research and design work required for the development of the productive forces of the near north. Bratsk has some facilities for training, including a number of vocational and specialized schools and a branch of the Irkutsk Polytechnical College which trains specialists in road transport, civil engineering, and energetics. Graduates from Bratsk educational institutions find it easier to adjust to living and working conditions in the northern regions. This is particularly important with respect to training personnel who will be assigned to work in areas that are being developed. At the same time, the process of strengthening Bratsk's scientific potential and transforming it into a large city improves conditions for achieving a high level of general and vocational training. It is natural to expect that priority should go to the training of specialists in a number of fields such as civil engineering, road facilities and, possibly, mining and timber industries.

The further development of the BITPC will lead to greater possibilities for research and design work, which are currently insignificant. Decisions made about problems relating to the development of the scientific and technical potential should take into consideration the corresponding requirements of other regions of the near north.

Once reserves of gas and oil are found on the territory of the Upper-Lena complex, it will be necessary to study ways of using them in the BITPC. One possibility is to use the gas as a highly efficient fuel for utilities and for technological purposes. Considering the need to protect the ecology of the cities, this might prove preferable to the use of coal supplied by other regions. Another possibility, which should be studied, is the development of a chemical industry on the basis of the Upper-Lena hydrocarbon raw materials. This plan must be considered along with other possible ways of locating chemical enterprises, including the possibility of building such enterprises on the territory of the Upper-Lena complex. The problem of the structure of the chemical complex must also be settled, and account must be taken of possible commercial reserves of common salt and the growing demand for chloro-containing compounds in the neighboring regions. Electrochemistry therefore appears to be the most promising branch of the chemical industry.

The territory of the BITPC may also be used for processing other kinds of minerals that might be extracted from the BAR area. Specifically, a copper-smelting plant could be located there that would make use of Udokan copper concentrates. Building such a plant in the immediate vicinity of the Udokan deposit is difficult because of the adverse natural and economic conditions. The idea for building a copper-smelting plant at the BITPC has certain advantages: the complex has a powerful building industry, which means that construction work can be done within a short period of time; there is ample power supply and a developed infrastructure; the distance which the raw materials would have to be transported (about 1500 km) is shorter than that connected with most other possible sites for this plant. However, this matter cannot be regarded as settled; a comparative study of all possible locations for this plant is needed, including its possible location in the southern part of the Chita Region.

There are other minerals, including asbestos, coking coal and aluminium, that can be supplied to the BITPC from the BAR area.

The construction of the BAR will improve the foreign trade prospects of the BITPC by facilitating the transportation of freight to the Pacific ports of the Soviet Union. On the one hand, the BAR will make it easier for the complex to export its products. On the other hand, the complex will have better opportunities for obtaining certain products in which it is interested. It may prove expedient to set up an alumina plant in the Far East near the ports. In that case the alumina can be transported to the Bratsk aluminium plant by the BAR. In principle, the alternative possibility of finding a site for an alumina plant on the territory of East Siberia cannot be ruled out, since costs for transporting high-grade bauxites cannot negatively affect the economics of alumina production.

The construction of the BAR makes it necessary to expand the transport network within the BITPC. Initially, attention will have to be focused on increasing the capacity of the Taishet-Bratsk-Ust-Kut Railway line which has already heavy traffic. In the future, traffic will increase considerably, even without the BAR, as more timber and iron-ore resources are involved in the economic turnover of the BITPC. But the most substantial increase in goods traffic will result from the construction of the BAR; thus measures are needed for increasing the traffic capacity along the length of the Railway.

Eventually it may prove desirable to build sections of the North-Siberian Railway on the territory of the BITPC. The Khrebtovaya-Ust-Ilimsk Railway line is already in operation; with its extension westward in the direction of the Boguchany HPS and further along the Angara toward Lesosibirsk and into Western Siberia, a new through Transsiberian Railway line will come into being that will considerably improve transport links in the latitudinal direction.

The provision of recreation facilities for the local population will also positively affect the transport links between the BITPC and the BAR area.

We have considered the basic trends in prospective links between the BITPC and the regions of the near north of East Siberia. As the productive forces develop and the economic situation changes, new possibilities will appear for establishing links. Only careful investigations will make it possible to determine more precisely the specific nature of the links and to establish their quantitative characteristics.

Analysis of Regional Strategy Setting

D.v. Winterfeldt

DECISION ANALYTIC APPROACH

This paper explores possibilities of using decision analysis for studying the process of strategy elaboration and selection in integrated regional development programs. Specifically, the paper seeks to generate further questions about the BITPC strategic decisionmaking process from the decision analytic perspective; and to generate questions about the strengths and weaknesses of the decision analytic approach itself.

WHAT IS DECISION ANALYSIS?

Decision analysis is a formal method for improving decision-making in complex situations characterized by multiple objectives, uncertainty, time variability, and group conflicts [1,2,3]. Decision analysis is a rational approach to structuring the decision problem, building a mathematical model of the decision-maker's preferences, and numerically evaluating the available decision alternatives. Decision analysis poses four classes of questions to the decision-maker and his experts. What are the problems and opportunities? What are the goals and objectives? What are the alternative courses of action and possible events and consequences? What are the tradeoffs that characterize the decision-maker's priorities among objectives, his risk attitudes, his time preferences, etc.?

The formalized answers to the first three questions are given in the form of qualitative trees:

- *A problem (or opportunity) tree* that establishes the hierarchical links among major problems, subproblems, and specific causes;
- *A goal tree* that shows the relationships among general supergoals, subgoals, major objectives, and lowest level targets and indicators;
- *A decision tree* that maps out alternative initial actions, possible subsequent events, follow-up actions, and consequences.

The formalized answers to the fourth question are numerical parameters that are to be incorporated in the decisionmaking model.

Such parameters are utility functions, importance weights, risk measures, and subjective discount rates. With these elements, decision analysis constructs a mathematical preference model (for example, a multiattribute expected utility model) with which alternative courses of action can be evaluated.

USE OF DECISION ANALYSIS FOR REGIONAL DECISIONMAKING

Decision analysis has been applied as a decision aiding tool in a large number of fields and decision problems [4,5]. Decision analysis may become useful for regional decisionmaking in areas such as facility siting, timing of construction activities, and environmental planning. However, decision analysis has never been applied to a problem as complex as regional strategy setting. Thus the present attempt is unique in that it seeks to apply decision analysis retrospectively, to study past decision processes rather than to aid present ones. Hopefully, a concise formalized characterization of past regional decision-making processes will prove helpful in present-day decision-making, both for the decision-maker and for the decision analyst. The decision-maker may learn from the case study useful ways to structure his problem; the analyst may be able to identify the difficulties of using such an approach.

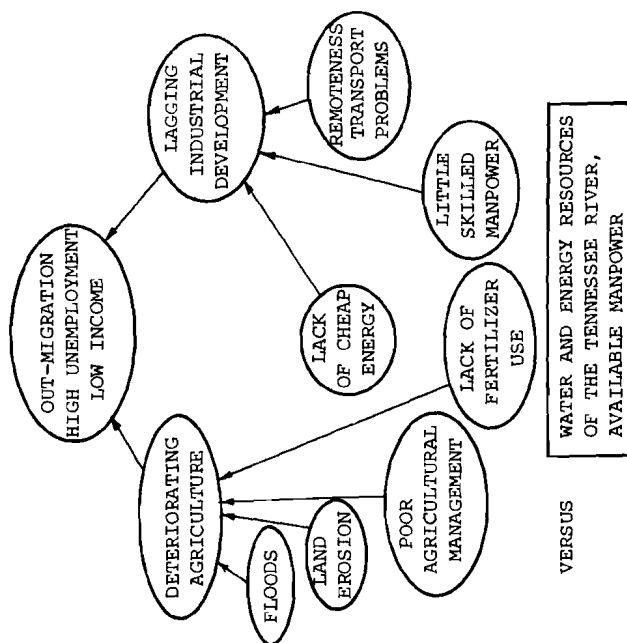
One may think of applying decision analysis retrospectively as a tool to evaluate the rationality of past decisions, but even a casual inspection of typical case material makes it clear that one cannot hope to obtain all the information needed for a full analysis and evaluation. Therefore, this paper makes a more modest attempt. It tries to formalize all the characteristics of strategic decisionmaking in the TVA and the BITPC cases (problems, goals, alternatives, and tradeoffs) that a decision analyst would have formalized if he had performed the analysis at the time the decisions were taken. That is, an attempt is made to reconstruct problem (opportunity) trees, goal trees, and decision trees, and to assess major tradeoffs. Since the decision analytic interpretation of the TVA and the BITPC regional strategies has to rely on limited case material, the results will necessarily be incomplete and tentative. Therefore, the analysis will probably raise more questions than provide answers.

ANALYSIS OF REGIONAL STRATEGY SETTING IN THE TVA AND THE BITPC CASES

Problems and Opportunities

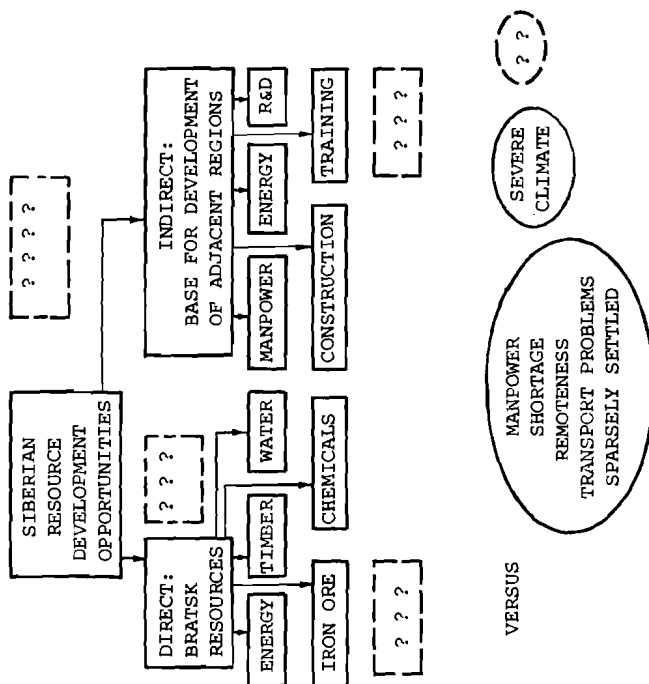
There were problems and opportunities that led up to strategic regional decisions in the TVA and the BITPC cases (Figure 1). The TVA can best be characterized as a *regional problem*. Clearly, there were some national considerations prior to the development of the TVA, such as interregional disequilibria and national defense considerations. But regional

TVA: A Regional Problem



VERSUS

BITPC: A National Opportunity



VERSUS

Figure 1. The TVA and the BITPC: tentative trees of problems (○) and opportunities (□).

problems dominated: low income, high unemployment, and out-migration. These problems were mainly a result of deteriorating agriculture and lagging industrial development in the region. These economic problems were in turn a consequence of such factors as land erosion, flooding, distance from attractive markets, lack of fertilizer use, of modern agricultural management, of cheap energy, and of skilled manpower. On the opportunity side were the water and energy resources of the Tennessee River, and a relatively large (though unskilled) manpower base.

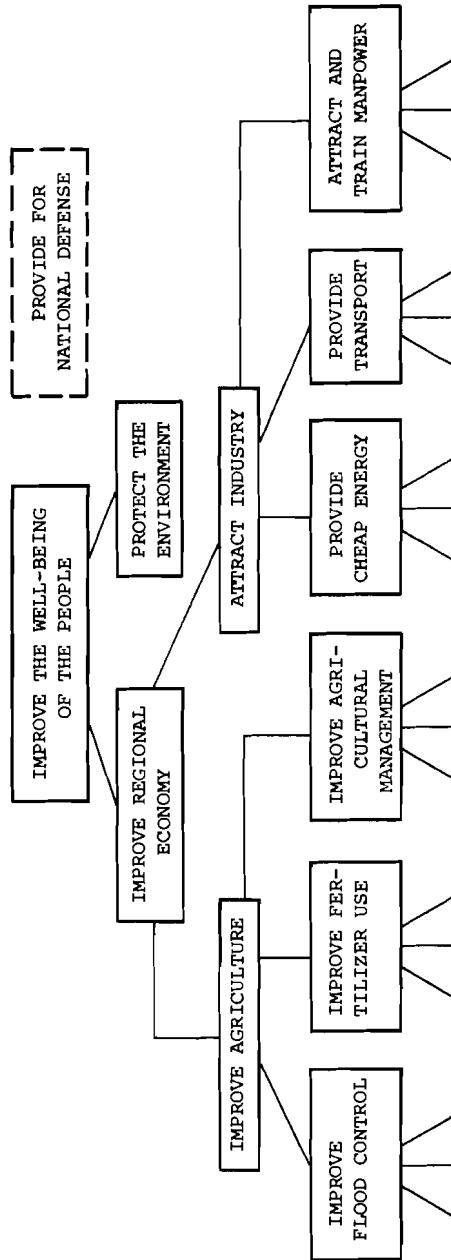
The BITPC development may be regarded as a *national opportunity*. The Bratsk-Ilimsk Region provided an excellent opportunity for the stepwise development of the East Siberian resources, particularly of the vast resources of the Angara-Yenisei Region. There seem to be at least two major aspects to this opportunity--the local resources of the Bratsk-Ilimsk Region (e.g., hydropower resources of the Angara River, timber, iron ore, and chemical raw materials); and the indirect opportunities that the BITPC could provide for the future development of adjacent regions.* For example, the BITPC could be used as a base for construction, technology, R & D, and energy. On the problem side were manpower shortages, transportation, severe climate, and sparse settlements. Of course, the opportunity tree is still tentative, and many boxes will have to be filled in.

Goals and Objectives

Attempts to structure goal trees from the case material proved difficult. There are many different structuring principles for goal trees, and results can differ substantially. Figure 2 represents my interpretation of the goals and objectives in the TVA case. The supergoal was to improve the well-being of the people in the Tennessee Valley. Another high level goal that recently almost faded in importance was the provision for national defense. Unfolding the tree, one could either logically specify the supergoal, or determine by which means one could achieve it. I selected the latter approach, and found that the main means considered for improving the well-being of the people was to improve the regional economy. The goal of environmental protection emerged only in the late 1960s, but has gained increasing importance. Further down in the hierarchy we find the more specific means to improve the regional economy by attracting new industry and improving the agriculture.

Most of these objectives coincide with the main goals set by the TVA act. Beyond these general statements very little is known, and it proved futile to determine more specific targets or measures against which regional strategies could be evaluated.

*See V.A. Shelest, *The Role of the BITPC in Solving Long-Term Development Problems of the Angara-Yenisei Region*, in this volume.



SPECIFIC SUBOBJECTIVES AND TARGETS

Figure 2. The goal tree, TVA.

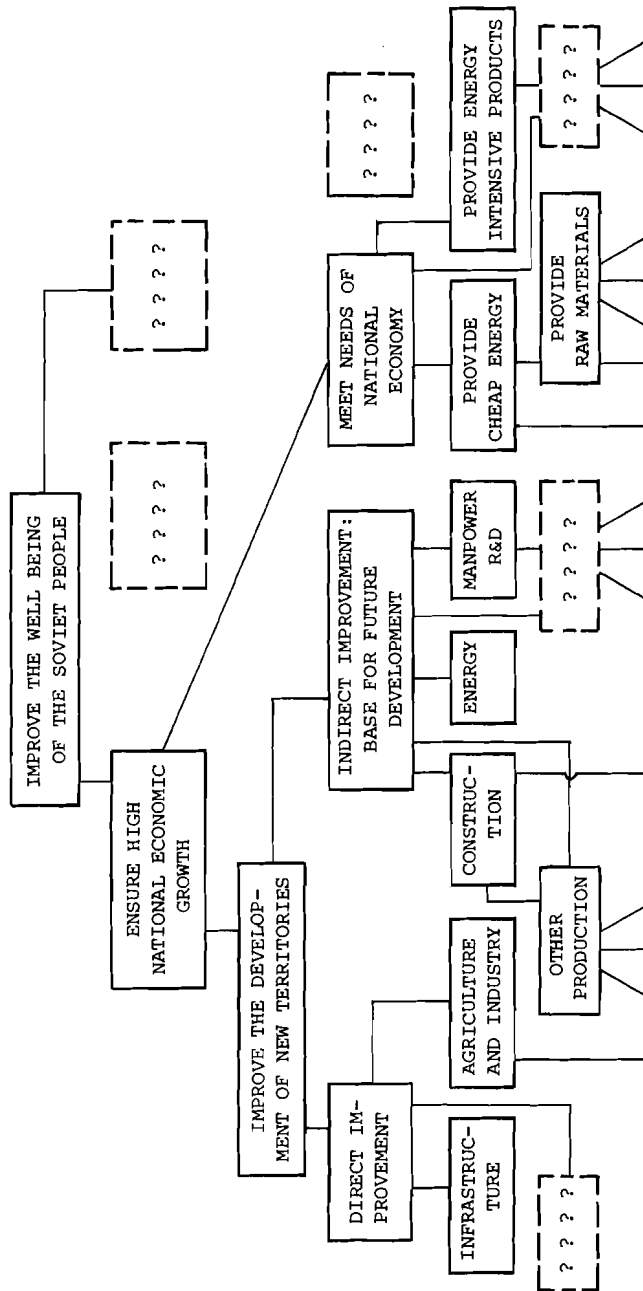
To study the goal structure in the BITPC, I used the same means-ends logic, together with a synthetic approach of collecting and integrating all the goal statements contained in the BITPC papers. Figure 3 presents my first attempt at the goal structure. Corresponding to the higher complexity of the BITPC development, the goal structure is more complex, and many important goal aspects need to be filled in. A frequently referred to supergoal was the improvement of the well-being of the Soviet people. There are many means and subgoals that would specify this supergoal, among them ensuring high national economic growth. For this first attempt, I concentrated on the specification of the national economic goal, but there are others. It seems to me that provision of national economic growth means, on the one hand, that resource development strategies for the BITPC should meet the requirements of the national economy for cheap energy, energy-intensive products, and raw materials. A somewhat independent subgoal seemed to be the development of new territories in East Siberia. This could have two objectives: direct improvement of new regions, and indirect improvement as a basis for the future development of adjacent regions. On the lowest level of the tree, I specified several possible aspects of direct and indirect improvement of new territories, and of meeting national economic needs.

This goal tree may be useful only in the first stage of analysis. We should explore further all the elements that have been left out of the tree; also, we should explore other logical ways of unfolding the tree.

Alternatives

Since one usually builds decision trees by looking into an uncertain future, the retrospective construction of such a tree is difficult. If one tries to construct the actual decision steps that were taken, the path through the decision tree becomes clear, but alternatives and, more importantly, the logic of the strategy unfolding are obscured. Therefore, I concentrated as a first approach on constructing trees that reflect the logic of strategy specification rather than on the actual actions and events that occurred. Actions and activities that were taken at each stage of the development had to reflect the logic that was iteratively generated through the decision process. The task of integrating an actual action and events tree in the logical strategic decision trees presented here remains one of the more important future tasks of decision analysis.

My attempt to build a decision tree in the TVA case is shown in Figure 4. The initial decision was to improve regional development by means of a federally financed program. Strongly discussed alternatives went as far as suggesting no federal actions. The second decision was to establish a governmental organization, staffed with a high degree of independence that would be ensured by no year money and flexibility in shifting appropriations among programs. In a market-oriented economy a clear alternative to this strategy would be to use incentive or regulatory programs to attract private enterprises and to support



SPECIFIC SUBOBJECTIVES AND TARGETS

Figure 3. BITPC: tentative goal tree.

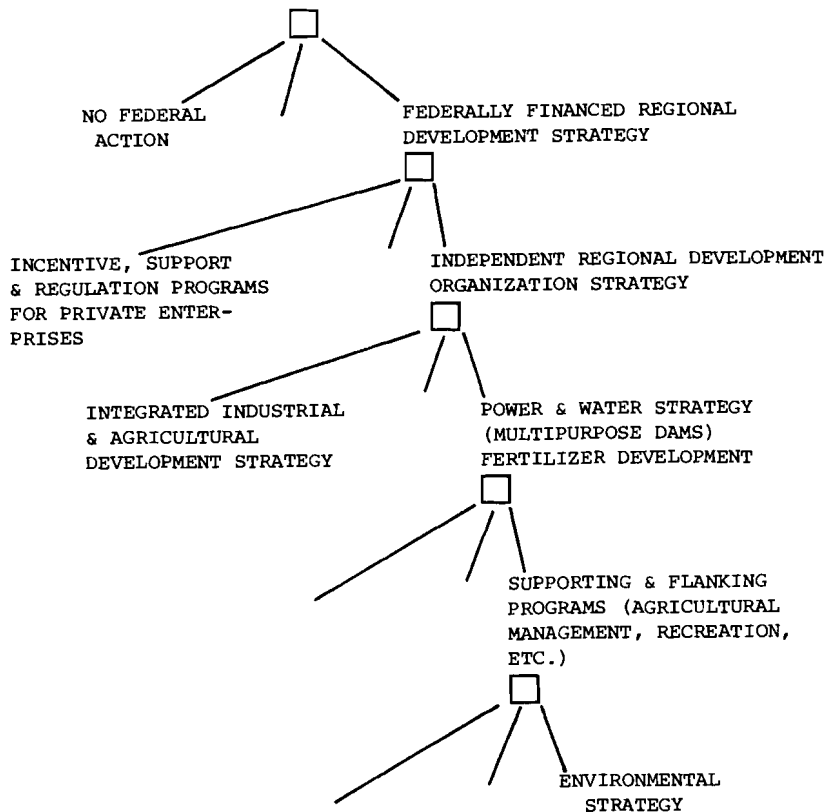


Figure 4. TVA: decision tree.

agricultural development. The substance of the TVA strategy was then decided to be a water and power strategy, and to concurrently build a base for fertilizer development. Added to this basic strategy were supporting and flanking programs to attract industry through information and incentives, to improve agricultural development through education programs, and to provide recreation facilities. More recent strategic decisions concerned mainly energy (coal versus nuclear), and environmental aspects.

As with the problem and goal tree, my attempt to create a decision tree in the BITPC case is still at a very early and tentative stage (Figure 5). The strategies for developing the Bratsk-Ilimsk Region were part of a grand scheme for the stepwise development of East Siberia. But within this scheme, several alternative steps were taken that seemed to be geared toward a complex and self-sufficient strategy rather than a strategy for supplying developed regions with raw materials. Clearly, one of the initial strategic decisions was to assign priority to the development of the East Siberian resources. The next decision was a settlement strategy, to develop energy resources and energy-intensive products with local raw materials. A conceivable alternative would have been to transport energy and raw materials

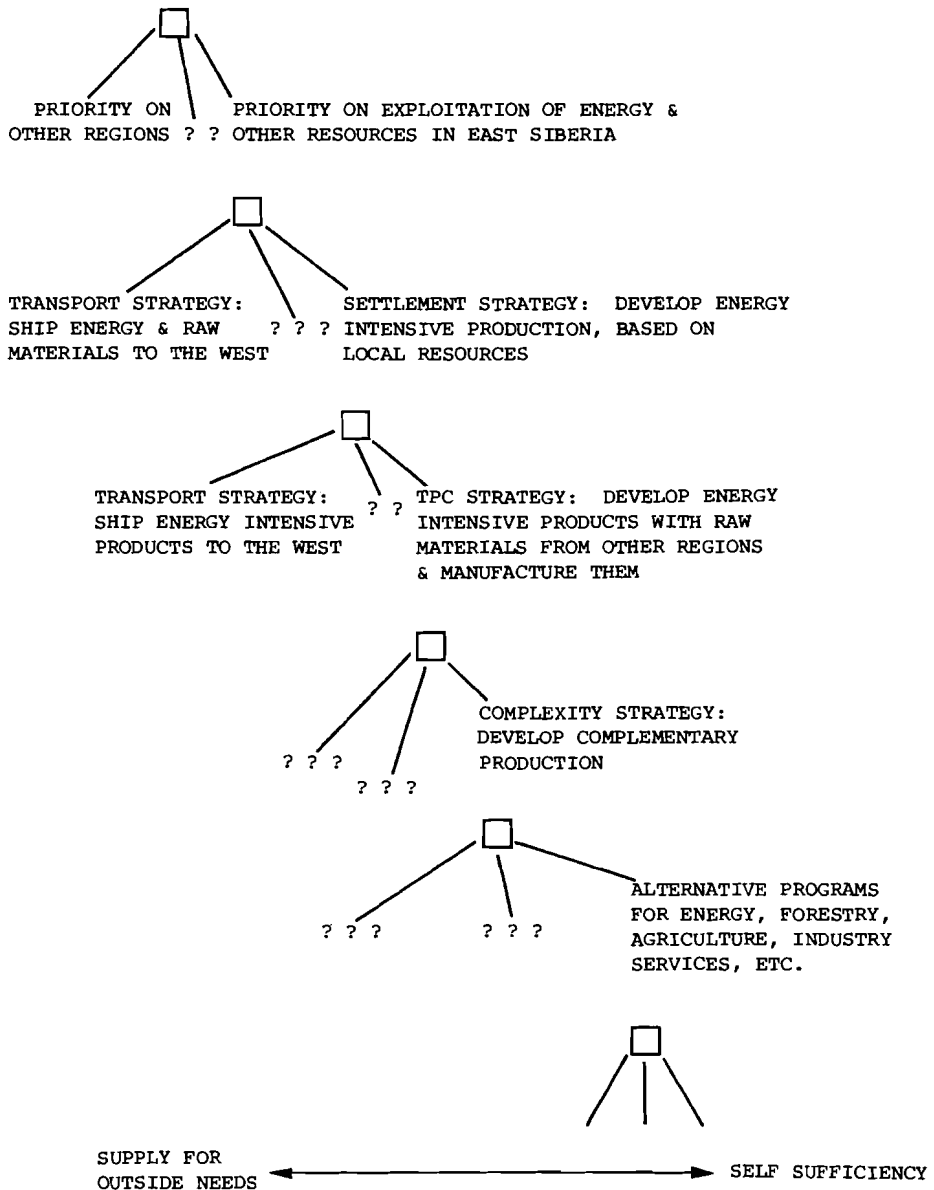


Figure 5. BITPC: tentative decision tree.

to the European part of the country. The TPC strategy taken subsequently went even further, namely to draw raw materials from other regions to develop energy-intensive products in the BITPC. A complementary or complexity strategy completed the strategic development--to develop products in the BITPC that complemented the local industrial development. Beyond these strategic decisions, several specific decisions had to be taken about program selection, timing, and location in the various BITPC sectors that reflected the strategic decision at each stage.

The implications for the specific regional decisions in the BITPC are strong. For example, the decision to build a powerful construction industry within the BITPC was the result of the self-sufficiency and settlement strategy connected with the envisaged future resource development strategies for adjacent regions. Similarly, the creation of a huge power reserve and the need to provide for attractive living conditions in the BITPC are a result of the strategic development scheme.

To complete the tree and to make it more realistic, I would need more information about possible alternatives (characterized in Figure 5 by question marks) that were discussed at the time the strategic decisions were made. I am uncertain about the relation between actual strategic decisions and the subsequent concrete actions. Finally, I would like to discuss how much expected or unexpected events influenced the decisionmaking process.

Preference Characteristics

In both the TVA and the BITPC cases, it proved very difficult to reconstruct the tradeoffs that guided decisionmaking. In the TVA, one can easily recognize the change from equally weighted goals (flood control, energy, and agricultural development) to the priority of energy objectives. These were later reduced in importance somewhat through the growing importance of environmental considerations. But the information is too limited to assess the major tradeoffs, let alone to construct a value model.

Some of the Conference papers have referred to value tradeoffs between sectorial and regional objectives, and between national and regional goals and interests*. But, in general, few explicit statements refer to tradeoffs between public and private consumption, navigation and energy production, environmental protection, costs for industrial location, etc. Another preference characteristic that a decision analyst would need to assess is time preferences, e.g., the tradeoff between deferred

*See L. Gramoteyeva, *Long-Term Planning in the USSR and Decision-making for the Development of the BITPC*, and V.P. Gukov and A.N. Semyonov, *Experience in the Formation of the BITPC*, in this volume.

private consumption now and increased private consumption in the future. Of similar importance is the problem of risk and risk-taking in strategic decisionmaking. Several papers have acknowledged the importance of uncertainty handling in decision-making. But little has been said about the mechanisms by which strategic decisions account for uncertainty. In the actual unfolding of the strategies in the BITPC, the way to handle risks is by an adaptive stepwise decisionmaking process; this seems like a risk averse strategy. On the other hand, some strategic decisions seem to have been motivated by undetected resources in East Siberia; this seems like a risky strategy. It would be interesting to explore to what degree risk taking is possibly confounded here with the time horizon of strategic decisionmaking.

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Management of the BITPC

V.P. Gukov and N.G. Perevalov

ECONOMIC EFFICIENCY OF TERRITORIAL-PRODUCTION UNITS

The economic efficiency accruing from improved spatial organization of the productive forces is determined by three basic factors: (a) technological cooperation for the joint use of raw materials by combining in one enterprise or center different production lines representing successive stages of raw material processing; (b) the establishment and operation of common auxiliary, transport and power units, water and heat supply and sewerage systems; and (c) the optimization of settlement patterns and the structure of the industries serving the population. The realization of each requires a commitment of financial and material resources and the involvement of appropriate bodies of state and economic management [1].

Social ownership of the means of production is the best possible means for meeting the increasing material and cultural requirements of society. In 1918, Lenin singled out among the top priority tasks for the country's economic development

... the rational distribution of industry in the Soviet Union from the standpoint of proximity to raw materials and the lowest consumption of labor power in the transition from the processing of the raw materials to all subsequent stages in the processing of semi-manufactured goods, up to and including the output of the finished product; ... the rational merging and concentration of industry in a few big enterprises from the standpoint of the most up-to-date large-scale industry, especially trusts ... [2].

Implementation of these ideas was started in 1920 with the Goelro Plan under Lenin's direction. The development of electric power generation was closely tied to the development of other branches of the national economy. Large district electric power stations would provide the basis for the economic activities of the surrounding territories. It was felt that in the course of the plan's implementation, territorial-production units would emerge in the European part of the country, and their development would be stimulated by the integrated power base. Therefore, in setting priorities and deadlines for the construction of electric power stations, the authors of the Goelro Plan were guided not only by the efficiency of power generation but also by the expediency of and the advantages offered by developing territorial-production units that might arise on the basis of the generated electric power.

The Dnieper power project is an excellent example of the improved territorial organization of the country's economy. Before the revolution, the Dnieper problem had been regarded as one of water transport and power production only; it was now approached from the viewpoint of comprehensively developing a group of allied industries on the basis of cheap electricity.

This systems approach to planning the development of the productive forces was further improved by elaborating the territorial aspect of the country's first Five-Year development Plan. In addition to more intensive planning methods for economic development during the 1930s, the systems approach was used in the design of various territorial-production units. The greatest success in this respect was achieved in designing the Maly Angarstroi project.

Currently, the problems of improving the territorial organization of the national economy are becoming increasingly urgent because of the growing complexity of the economy's patterns and its enlarged scope. The planning of economic advancement in the USSR is done by planning bodies who base their work on scientific studies by numerous branch, integrated R&D and project planning organizations. The USSR State Construction Management Agency has organized specialized project planning agencies--institutes for town planning and departments for designing industrial units at territorial project planning institutes.

The joint efforts of project planning organizations and planning bodies have resulted in projects of district layouts of industrial and agricultural areas, and in plans of towns and master plans for locating groups of industrial enterprises on one construction site. The implementation of these projects yields an appreciable economy to the State. For example, the transition from an individual location of enterprises to a group pattern reduces the number of workers by 10 to 37 percent, depending on the type of industries being united, and the length of communication lines by about 15 percent. The savings in capital investments range from 4 to 39 percent, with the average being about 10 percent [3]. Thus, there is a more optimal use of natural and human resources and capital investments. The savings realized from improved territorial organization are shown in Table 1 for several kinds of territorial-production units. It can be seen that economies are achieved by reducing capital investments for construction and operating costs.

The efficiency of the territorial organization of social production largely depends on the location and capacity of auxiliary industries and institutions of the nonmaterial sphere that are set up in various territorial-production units. Each level of a territorial unit includes smaller territorial subunits. Therefore industries and services change when passing from a lower to a higher territorial-production unit. In cases of lesser requirements for goods or services or of greater transportability, enterprises and institutions with a considerable range of operations will appear.

Table 1. Savings realized from improved territorial organization.

Indices	Site	Town	Industrial Unit	Territorial Production Complex
<u>I. Reducing expenditure for construction</u>				
1. Engineering preparation of territory	++	++	+	-
2. Local transport communications	++	++	+	-
3. Water supply and sewerage systems	++	++	+	-
4. Steam lines	++	-	-	-
5. Thermal pipelines	++	++	+	-
6. Electric transmission lines	++	++	++	++
7. Auxiliary facilities	+	++	++	++
8. Construction base	+	++	++	++
9. Civil infrastructure	-	++	++	+
<u>II. Reducing operating costs</u>				
1. Local transport	++	++	+	+
2. Water supply and sewerage systems	++	++	+	-
3. Thermal and power supply systems	++	++	+	-
4. Auxiliary and storage facilities	+	++	++	-
5. Construction base	+	++	++	+
6. Civil infrastructure	-	++	++	+
(++ considerable, + insignificant, - negligible.)				

Territorial-production complexes (TPCs) are one of the links in the system of territorial organization of the productive forces in the USSR. Targets for the major TPCs, as far as developing the leading branches of their economies, are fixed in the State plan [4, pp.258,260,268,269,276].

Such targets have also been set for the BITPC. The current Five-Year Plan envisages the completion of the construction in

the BITPC of an aluminium plant, a timber production complex, a heating equipment plant, a furniture factory, a garment factory, the first eight units of the Ust-Ilimsk hydropower station (HPS) with a total capacity of 1.9 million kW, as well as the start of the building of the Ust-Ilimsk pulp mill [4, p.259-260].

PLANNING AND MANAGEMENT OF A TERRITORIAL-PRODUCTION COMPLEX

The TPC is part of the country's national economy, comprising the territory of several basic administrative districts. The TPC solves one or several major interconnected economic problems, with account taken of the geographic position, the economic potential, and the availability of natural and manpower resources. A productive and social infrastructure is formed, and technologically interrelated enterprises are built on the complex. As a rule, the TPC appears after a plan for its development has been elaborated. Usually, a complex includes several towns and dozens of industrial and agricultural settlements which gravitate economically to the TPC core, the latter being the largest industrial center.

The TPC is a separate object for planning and management, inasmuch as solutions to major economic branch problems require the creation of auxiliary industries and services. Therefore it is necessary to coordinate branch and territorial planning on the TPC level.

Having definite economic integrity, the TPC maintains numerous economic ties with other parts of the country's economy. Nevertheless, its economic and technological ties are closer and it exerts a more profound influence on the efficiency of the complexes connected with it.

On the TPC level, it is necessary first to ensure the fullest possible satisfaction of the population's requirements: to provide all able-bodied persons with work, to ensure rational settlement patterns, to develop everyday services, etc. The synchronous commissioning of interdependent technological projects, the rational development of auxiliary industries, transport, power, fuel and water supply, are some of the problems that are tackled.

Since there are a considerable number of departments involved in the planning and management of the TPC, it is necessary to coordinate the activities of the enterprises and organizations of TPC, especially at the construction stage.

The TPC cannot, as a rule, be limited to one administrative district, whose concern is primarily with the daily management of agricultural production and the provision of administrative and legal services for the population. The TPC occupies the territory of several administrative districts. Therefore, a major role in the development of the TPC is played by the regional, republic and union planning and management bodies and, primarily by the regional Soviets of working people's deputies.

CHARACTERISTICS OF THE BITPC

The background and historical development of the BITPC has been discussed in detail elsewhere in this volume.* We will therefore focus attention on the organizational aspects of the BITPC (Figure 1).

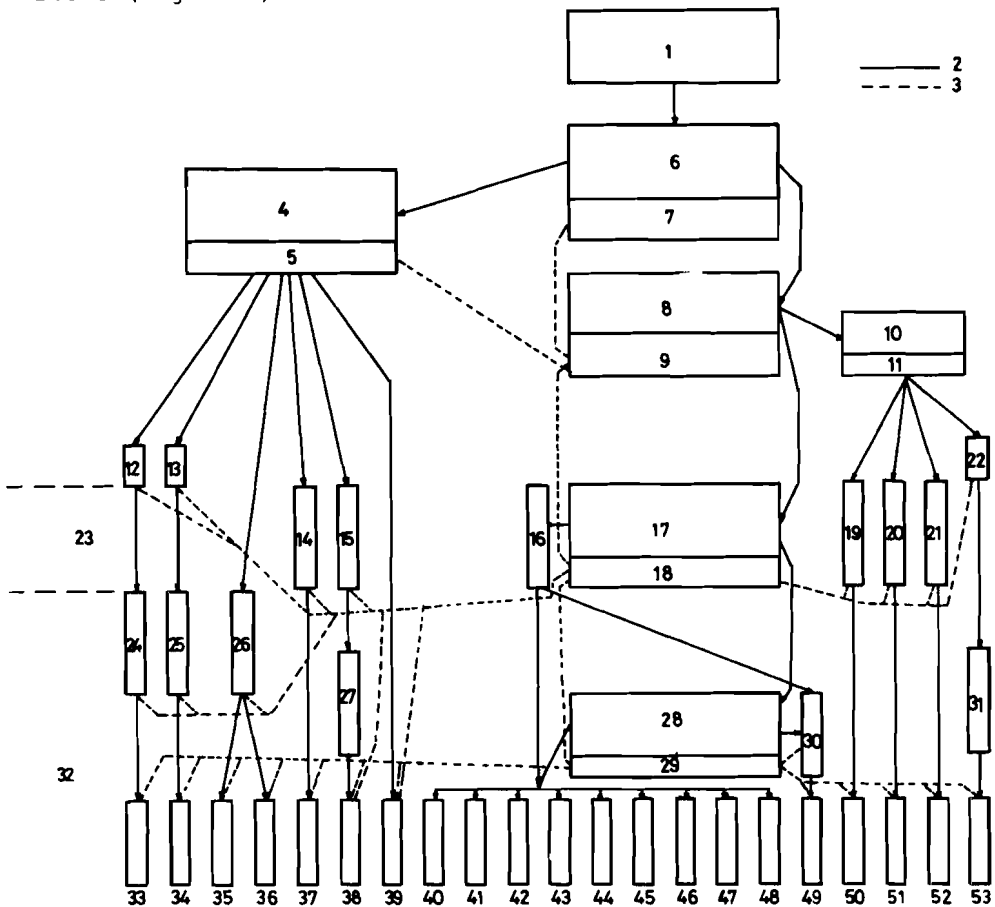


Figure 1. Subordination organizational chart of the projects of the BITPC.
(See below and next page for key.)

- | | |
|----------------------------------|-----------------------------------|
| 1. USSR Supreme Soviet; | 5. Head Departments; |
| 2. Administrative Subordination; | 6. USSR Council of Ministers; |
| 3. Planning Connections; | 7. USSR State Planning Committee; |
| 4. Union Ministries; | |

*See N.A. Soloviev and K.Ya. Donchenko, *The Role of Republic and Local Planning and Management Bodies in the Development of the BITPC*, in this volume.

- | | |
|--|---|
| 8. Council of Ministers of the Russian Federation; | 35. Building Materials Enterprises; |
| 9. State Planning Committee of the Russian Federation; | 36. Construction and Erection Departments; |
| 10. Republican Ministries; | 37. Hydropower Stations, Electric Steam Stations; |
| 11. Head Departments; | 38. Timber Procurement and Wood Chemistry Enterprises; |
| 12. Department; | 39. Timber Production Complexes, Heating Equipment Plant; |
| 13. Department; | 40. Bakeries, Mechanical Bakeries; |
| 14. Department; | 41. Education; |
| 15. Association; | 42. Public Health Services; |
| 16. Sections and Departments; | 43. Culture; |
| 17. Regional Executive Committee; | 44. Trade; |
| 18. Planning Commission; | 45. Public Utilities and Social Services; |
| 19. Department; | 46. Social Security; |
| 20. Department; | 47. Financial Bodies; |
| 21. Department; | 48. Municipal Services; |
| 22. Department; | 49. State Farms; |
| 23. Regional Level; | 50. Meat Packing Plants, Dairy Plants; |
| 24. Railway Board; | 51. Clothing Factory; |
| 25. Aircraft Works; | 52. Motor Depot; |
| 26. Construction Department; | 53. Piers and Moorages. |
| 27. Integrated Plant; | |
| 28. District (City) Executive Committee; | |
| 29. Planning Commission; | |
| 30. Department; | |
| 31. Enterprise; | |
| 32. TPC Level; | |
| 33. Railway Stations; | |
| 34. Airports, Airfields; | |

The construction and functioning of these specialized enterprises are based on the TPC's building materials industry, heat and power engineering, repair and transport facilities, etc. Housing and communal service facilities, health services, educational establishments and cultural institutions have been set up. Enterprises of light industries and the food industry, and suburban agricultural production have been organized. As a result, normal living conditions have been ensured for the population.

Branches of countrywide specialization of the Complex now account for 89.5 percent of its gross industrial output. The Complex produces 3 percent of the country's supply of electricity; 7.3 percent of cellulose; 5.9 percent of cardboard; 8.3 percent of iron ore, and 3 percent of workable wood for industrial purposes.

Specialized enterprises belong to different departments. Hydropower stations come under the supervision of the district electric power board, and in terms of their operations they are subordinated to the dispatching office of the Siberian power grid. Timber production complexes, the aluminium plant, and the ore-dressing plant are subordinated to the corresponding departments of the Union ministries. Timber procurement plants are combined to make two integrated plants that form a part of the production association accountable to a Union ministry.

The leading building organizations (i.e., the specialized department for the construction of the Bratsk hydropower project, and departments for the construction of transportation facilities of the Angara project) come under the jurisdiction of Union ministries. In turn, these building organizations supervise the activities of the enterprises of the building materials industry organized within the framework of the complex.

Enterprises of the timber industry, public health, education, culture, trade, and communal organizations, public utilities, social services, and social security agencies in towns and districts are run by the City and District Soviets and by the corresponding bodies under the Regional Soviet Executive Committee. This allows the Soviets to exercise daily control over these enterprises and organizations.

Nevertheless, the various elements of the TPC economy are united by the common territory and a common basic task--that of raising the living standards of the TPC population. Rules and regulations have evolved that ensure the most effective development of the TPC economy.

The September 1965 Plenary Session of the Central Committee of the CPSU, and the 23rd and 24th CPSU Congresses devoted considerable attention to the problems of improving the economic development of the country. They recommended greater use of economic methods and incentives for managing the country's economy, increased economic independence and more initiatives for enterprises, increased material interest on the part of the working people in the results of their activities, enhanced responsibility for these results, and an improved state planning system.

The TPC is not a structural link in the administration system; it is an object of planning. The experience of the creation of the BITPC has shown that the existing legal and legislative norms make it possible to manage the formation of the complex.

The development of the economy in the Mid-Angara Region was preceded by a thorough research and project planning work which made it possible to evolve a strategy for developing the unique natural resources of the Region. The results of research at the first stage of this development were summarized in two documents prepared by the project planning organizations. The Gidroenergo-proekt, in the early 1950s, created a project for developing the economy in the Bratsk HPS zone of operation, while later the State Institute for Town Planning designed the district layout of the Bratsk power and industrial complex [5, p.99]. These served as the bases for adopting the decision of the USSR Council of Ministers on the economic development of the Mid-Angara Region. Most important was the Decree of the USSR Council of Ministers, of September 11 1956, on the organization in Bratsk of a common base for building a HPS, industrial enterprises, and civil engineering projects in the area of the Bratsk HPS construction site [6, pp.116-119].

Five-year plans are the principal planning documents for developing the complex. They set the tasks for each year, and specify the key targets for each quarter period. Five-year plan targets are adjusted, if necessary, while yearly plans are approved; this makes it possible to account for changes. Planned assignments are similar to what is usually termed decisions or guiding information. The plan is the law for production in the Soviet economy.

Involved in the planning process of the economy of the complex are enterprises and institutions of the TPC, district and town planning committees, regional boards and regional planning committees, union and republic ministries and departments, the Republic Planning Committee, and the USSR State Planning Committee.

Recently the Councils of Ministers of the USSR and the Council of Ministers of the Russian Federation adopted decisions extending the rights and duties of the local planning and executive bodies in planning and supervising the activities of enterprises not directly under their jurisdiction. In August 1968, the Council of Ministers of the Russian Federation gave the regional planning committees the right to draw up plans for the economy of the region, irrespective of departmental subordination of enterprises. These committees review and coordinate the five-year and the annual plans of all enterprises of the territory under their jurisdiction; thus there is a more balanced plan for producing goods and household utensils and for housing, and communal construction [7].

The enterprises and organizations of the territory share a common interest in using the manpower resources, local agricultural produce, and the resources of multi-sectorial importance (e.g. electric and heat energy, local building materials). Coordinating the development of the TPC's economy with the development of housing and cultural construction and that of cultural, educational and public health projects is of great importance.

The regional planning committee, with the participation of the city and district planning and executive bodies, draws up plans for each of the districts and towns under its jurisdiction. Adjustments are made to the plan in accordance with the actual situation in the given localities. The common economic interests of neighboring districts and towns are duly taken into account in drawing up the plans. Thus, in the BITPC this is clearly manifested in the plans for capital construction. A single plan is drawn up for the building organization that is charged with the construction on the complex, regardless of the departmental affiliation of the customer. Planning work for railway, air and water transport is done through appropriate departments that serve all enterprises of the complex.

Apart from planning and managing the economy of the locality within their jurisdiction, the regional Soviets of working

people's deputies give their opinion on the recommendations of the ministries that deal with the creation or expansion of industries within their jurisdiction. Without the consent of the regional or district Soviet, a ministry cannot start construction, expansion, or reconstruction. This contributes to an effective control over the development of the complex. City and district organizations, together with their regional counterpart, are represented on the board of experts in charge of project examination. The city and district Soviets have the right to make final decisions on a number of questions; this results in better coordination of the economic development of individual towns and districts of the region.

The regional, district, and city organizations devote much attention to coordinating the growing requirements for manpower, and the availability of such as a result of natural population growth, manpower redistribution among various enterprises and institutions, and organized resettlement from other districts of the region and the country. Plans for capital construction are carefully worked out and coordinated with the development plans for production capacities of local building organizations. The plan for developing agricultural production is drawn up separately in each district with a view to satisfying the population's requirements for perishable and nontransferable foodstuffs. The plans for capital construction and those for education, culture and public health take into account the envisaged population growth.

Coordinated plans for economic development on the local, republic and union levels are not enough for the balanced development of the TPC. The local Soviets and their planning bodies actively influence the fulfilment of targets by those union and union-republic enterprises that produce consumer goods, local building materials, housing and cultural construction, and services. The local Soviets have no authority to interfere in the daily economic activities of organizations not under their jurisdiction, or to give orders regarding outlays for various purposes; they can, however, discuss reports by heads of these enterprises, checking that the latter has complied with existing legislation.

In accordance with the existing legislation, the local Soviets sponsor the joint use of means allocated to all enterprises, institutions, and organizations of their territory for organizing public services and implementing social and cultural measures in the populated centers. The Bratsk City Soviet has set up an urban construction directorate in charge of building municipal economy projects.

The district and city Soviets hold annual sessions at which they discuss and approve economic development plans and the budget. The budget takes into account the economic activities of all enterprises located on the given territory. The local Soviets are interested in increasing the profitability of all enterprises since this has a direct effect on the budget.

The organizational links between the local Soviets and the organizations outside their jurisdiction are constantly perfected. Currently, electing local Soviets as heads of the leading enterprises and organizations not within their jurisdiction is practised on a wide scale, for example, in Bratsk. Their active participation in the work of the city Soviet ensures the successful fulfilment of the comprehensive plan of urban development and a fuller satisfaction of the everyday needs of the population. The responsibility of economic managers for fulfilling the Soviets' decisions is increased owing to their accountability to their electorate.

One form of local Soviet influence on organizations not subordinated to it is the examination of the organization's activities by deputy commissions. These commissions enlist the help of representatives of the organization concerned with adopting recommendations and checking their implementation. Joint decisions are made by the local Soviets and the heads of organizations outside the Soviets' jurisdiction on such matters as the organization's participation in the development of municipal economy, and housing construction.

The local Soviets have broad responsibility for supervising the use of land, forests and water resources, and on environmental matters. Their role in these matters has increased recently, following the adoption of new legislation.

Communist Party bodies have played an important role in solving questions pertaining to the planning and management of the BITPC. The CPSU guides the creative activities of the Soviet people and works out the scientifically-based domestic and foreign policy of the Soviet state. It coordinates and guides the work of all state and public bodies. The party is organized on a territorial-production principle: local party organizations are created at places of work where the Communists are united in district, city and other territorial organizations. They implement the party policy in all fields, including the economic sphere, within their territorial limits.

From the beginning of the industrial development of the natural resources in the Mid-Angara Region, the Irkutsk Regional Committee of the CPSU has played an important role in the development of the BITPC. In June 1955, the Regional Committee of the CPSU decided to dispatch the most active members of the Communist Party and the Komsomol from industrial enterprises and construction projects in the Region to work on the construction site of the Bratsk HPS [6, p.58]. This strengthened the project's party organization and stimulated it to more actively participate in solving questions of production and daily living. In the initial period of construction, the Regional Committee assisted in improving the living conditions of the workers and in accelerating the construction of the electric power transmission line between Irkutsk and Bratsk. Later, the Regional Committee made decisions aimed at fulfilling the plan for the organization of the complex [6, pp.83-84, 102-105].

The Bratsk city and district committees, and the Ust-Ilimsk and Nizhne-Ilimsk district party committees, the party committees and organizations at the enterprises and construction sites devote much attention to the overall development of the BITPC. The workers are encouraged to successfully fulfil the plan targets, and party organizations require that economic managers do all they can to meet plan targets.

In the discussion of the BITPC, one should mention the role of the specialized department, Bratskgesstroi, in the building and functioning of the complex.

The Bratskgesstroi was formed as an association of enterprises. Included in Bratskgesstroi are general and specialized construction units, plants for producing local building materials, repair shops for building and transport machinery, factories producing specialized equipment, fittings, and goods necessary for construction. It organizes and supervises the activities of the housing fund, heat and power supply networks, and the water supply and sewerage systems of the complex. The organization has large specialized transport units, and supervises the system for supplying food products and consumer goods, and organizes public catering. It has its own project planning body that works for its units, and there are centers for vocational training and in-service training (Figure 2).

During the initial stage of the development of the Mid-Angara Region, most of the able-bodied people in the complex worked at the enterprises and other bodies of Bratskgesstroi. Currently, this number has dropped to about one-half. Even now about three-fourths of the population of the complex are recipients of the services of Bratskgesstroi.

Concentrating the material, financial and manpower resources in one organization has contributed to the optimal utilization of these resources by the complex. The success of Bratskgesstroi is the result of skillful decision making on the part of the organization's leaders.

The experience of the BITPC has shown that the existing forms of management of the complex do not always provide an opportunity for adopting effective decisions timely and efficiently. This is because the interests of ministries as represented by enterprises within their jurisdiction and the interests of the territory do not always coincide.

Principal discussion is centered around questions of planning and managing capital construction, and the creation and maintenance of the infrastructure, since the existing economic mechanism strictly regulates the relations among operating enterprises. If adopted obligations are violated, the losses incurred should be compensated. However, so far it has not been possible to agree on this issue.

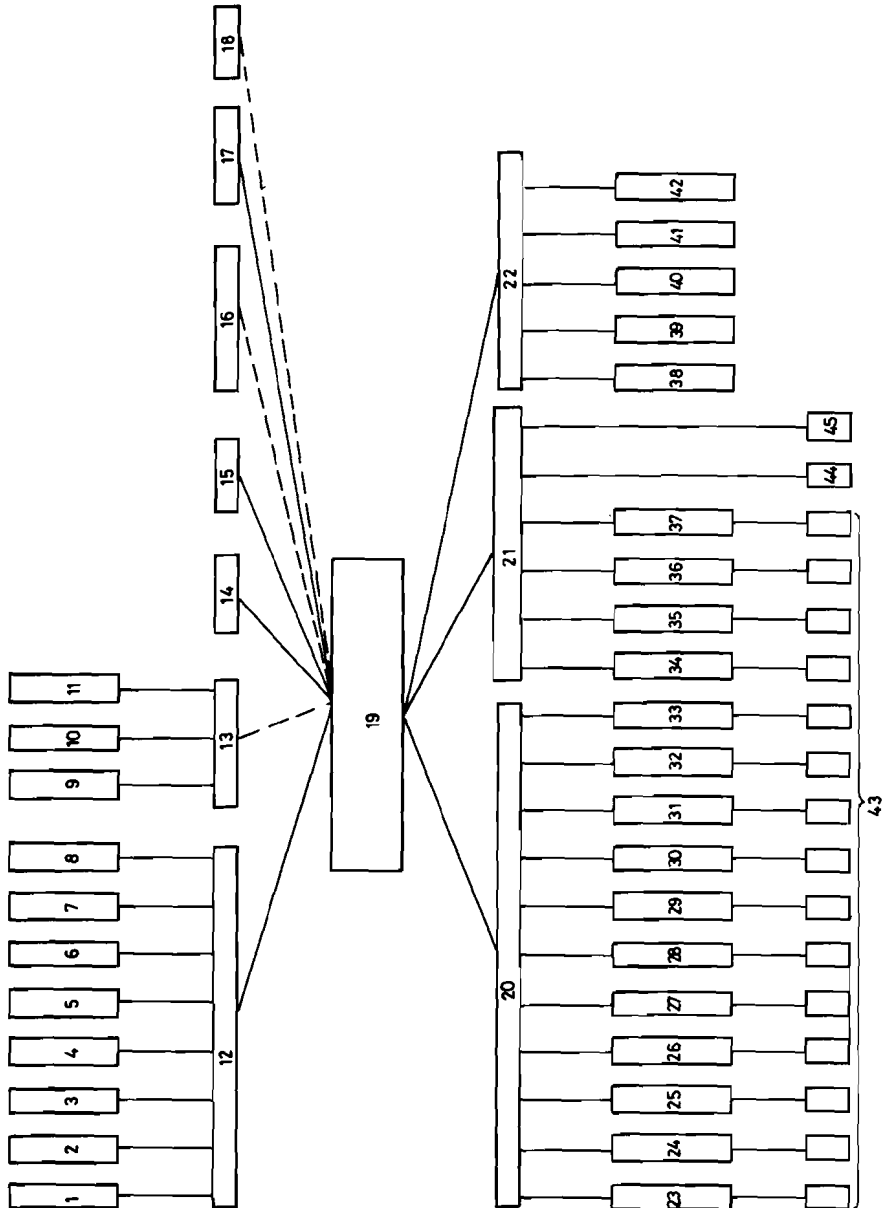


Figure 2. Structure of Bratskgesstroi.
(See next page for key.)

- | | |
|---|--|
| 1. Motor Transport; | 24. Ust-Ilimsk Timber Production Complex; |
| 2. Chief Power Engineer; | 25. Ust-Ilimsk; |
| 3. Water Supply and Sewerage System; | 26. Timber Procurement Center of Ust-Ilimsk Timber Production Complex; |
| 4. Railway Transport; | 27. Korshunovo Ore Dressing Plant; |
| 5. Material and Technical Supply; | 28. Bratsk; |
| 6. Hydroengineering Unit; | 29. Bratsk Aluminium Works; |
| 7. Chief Mechanic's Spare Parts Depot; | 30. Bratsk Timber Production Complex; |
| 8. Housing and Municipal Services; | 31. Industrial and Agricultural Enterprises; |
| 9. Ministry of Power Engineering and Electrification; | 32. Power Lines and Substations; |
| 10. Ministry of Construction and Erection; | 33. Capital Repairs; |
| 11. Other Ministries and Departments; | 34. Road Construction; |
| 12. Auxiliary and Other Services; | 35. Excavation and Tractor Work; |
| 13. Subcontracting Organizations; | 36. Sanitary Engineering and Assembly Work; |
| 14. Drafting Body; | 37. Mechanization of Construction; |
| 15. Training Centers; | 38. Integrated Plant Zhelezobeton; |
| 16. Department of Workers' Supply; | 39. Timber Industry Departments; |
| 17. Computing Center; | 40. Mechanical Repair Works; |
| 18. Recreation Centers; | 41. Motor Vehicle Repair Works; |
| 19. Specialized Department Bratskgesstroi; | 42. Sanitary Engineering Plant; |
| 20. General Contracting Organizations; | 43. Construction and Erection Divisions; |
| 21. Specialized Organizations; | 44. Communications; |
| 22. Industrial Enterprises; | 45. Small-Scale Mechanization. |
| 23. Ust-Ilimsk Hydropower Station; | |

Based on the experience of the BITPC, we deem it necessary to set up a body for managing the complex which would be responsible for solving questions pertaining to capital construction and the formation of the infrastructure. The success of the development depends largely on the success of the construction activities and on the development of the infrastructure. First, it is necessary to organize a body for managing the TPC; this body should have rights similar to those of the departments of the Regional Executive Committee (e.g., the head should have the powers of Deputy Chairman of the Regional Executive Committee). This body should be set up in the largest industrial center of the complex--Bratsk [8].

The Planning Committee of the TPC should have the right to apply directly to the State Planning Committee and to the State Planning Committee of the Russian Federation to solve various

problems related to the development of branches of countrywide specialization.

The financing of the TPC should be from one source on the basis of the TPC project approved by the Government. This is an essential condition inasmuch as the implementation of the project requires considerable allocations, and also, the interests of several ministries are involved. As for construction which will require state bank credits and the use of accumulated funds, it should be agreed upon with the managing body since building organizations will be within its jurisdiction.

As to fund allocations for the creation of the TPC, the TPC management body should be in contact with the State Planning Committee and not with individual ministries.

When an enterprise is commissioned, cost accounting relations should be established between the enterprise and the TPC management body. Enterprises should cover the expenses for maintaining the infrastructure. If an enterprise intends to carry on reconstruction work that will result in an increase in products or services received from the infrastructure of the TPC as well as in the number of workers, it should turn over the necessary capital investments to the TPC management body before reconstruction begins. Payment for the creation and exploitation of the industrial infrastructure should be fixed on the basis of the norms of consumption of its products and services. As for the social infrastructure, the degree of participation of various enterprises in its creation should be differentiated depending on the number and category (first, second and third members of the family) of the working people.

Testing these proposals will make it possible to improve the management system of the TPCs being formed, and to raise the efficiency of operations.

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An Organizational Approach to the BITPC

C. Davies, A. Demb, and R. Espejo

INTRODUCTION

This paper discusses the BITPC from an organizational perspective. Although all Conference papers are of interest, we have paid particular attention to the paper by Gukov and Perevalov,* and to a lesser extent, to those by Gramoteyeva,** and by Soloviev and Donchenko.*** We are fully aware of the magnitude of the task that the Soviet team must have faced in describing this complex system in these short papers. We congratulate them on the quality of the job they have done. The authors have provided us with a sound basis for further discussions.

This presentation describes the central concept of the case analyses of organizations of regional development; this is used as background for discussions in relation to the BITPC. Since time is limited, our discussion cannot reflect either the full complexity of the analytic framework or the theoretical foundations. The details of the analytic framework are presented in [1], a separate Working Paper whose discussion would be welcome at another time.

We hope to use BITPC as one of five studies of regional development carried out in different national settings. These cases are Tennessee, Bratsk-Ilimsk, Lublin-Vistula, Guyana (Venezuela), and Scotland. The framework we describe will be applied consistently to each case, and our belief is that by providing parallel descriptions of different cases new insights into regional development will result.

Our purpose in studying several cases in parallel differs from research that attempts to evaluate organization form in

*See V. Gukov and N. Perevalov, *Management of the BITPC*, in this volume.

**See L. Gramoteyeva, *Long-Term Planning in the USSR and Decisionmaking in the Development of the BITPC*, in this volume.

***See N. Soloviev and K. Donchenko, *The Role of Republic and Local Planning and Management Bodies in the Development of the BITPC*, in this volume.

order to find a "best" solution. We recognize that organizational responses reflect the economic and social characteristics of the national settings as well as the particularities of the specific development programs. Our case study approach focuses on the organizational responses within a national setting. By constructing parallel analyses of five cases representing different socio-economic settings, we hope to contribute to an understanding of universal factors that may be operating, and of the preconditions that may be required for the successful application of a particular solution.

CONCEPTUAL BASIS FOR CASE ANALYSIS

We have posed a definition of regional development which is consistent with the aims of our organizational analysis (Figure 1). Such development programs are the result of a

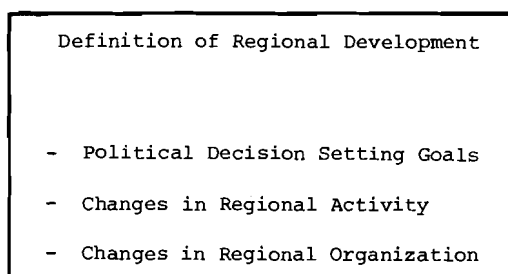


Figure 1.

political decision that sets development goals, the achievement of which implies a change from the ongoing development process in the region. It is the management of this change process that provides the logic for our analysis.

The focus of the analysis is the multiorganization for regional development, i.e., the system of organizations distinctly involved with the regional program. A major initial research task is the delineation of this regional system.

The analysis traces the changes incurred in the region as a result of the policy decision to create an integrated regional development scheme. As such it seeks to describe three elements in the process of change:

- The organizations existing in the region prior to the development program. We assume that activities are

ongoing in the region and that there are many types of organizations associated with these (Figure 2); the particular classes of organizations may vary greatly between national settings.

- The process leading to the policy decision.
- The change in organization and activity incurred as a result of the program (Figure 3).

Directing attention to the organizational "solution" to the management of the development scheme, we find that it will perhaps involve a new agency and new linkages between regional organizations and between outside organizations (largely central government). The nature of the final organization will also vary according to the national setting and to the development plan.

The information generated in the description of the multi-organization and the three elements of the change process provide the basis for further analysis. A detailed description is presented in [1]. For our purposes here we note only that the analysis rests on the notion of consistency. Consistency analysis is aimed at elucidating the organizational mechanisms created to support the regional program and at examining whether these mechanisms allow the organizations of the regional system to be effective in their management of the regional development program. The analysis is completely internal to each particular case.

DISCUSSION POINTS

Our discussion points have been selected to add to our understanding of the mechanisms supporting the creation and operation of the regional system of organizations. Our first point, *visibility*, is directed to help us delineate the boundaries of this system; *integration*, *coordination*, and *conflict resolution* deal with important aspects of its operation. The final point considers the organization Bratskgesstroi--both its external linkages and internal operations. This, thus, goes beyond the scope of the multiorganizational approach.

Visibility of the BITPC

A major concern in any development scheme is that the development concept should be a significant force in the region. We were interested to learn that BITPC is an object of planning rather than a structural link in the administrative system. We would like to understand better the relevance of this object of planning to the organizations operating and the people living on the BITPC territory. In what way is their behavior modified by the BITPC concept?

A criterion for the relevance or visibility of the development scheme is the extent to which organizations operating seek

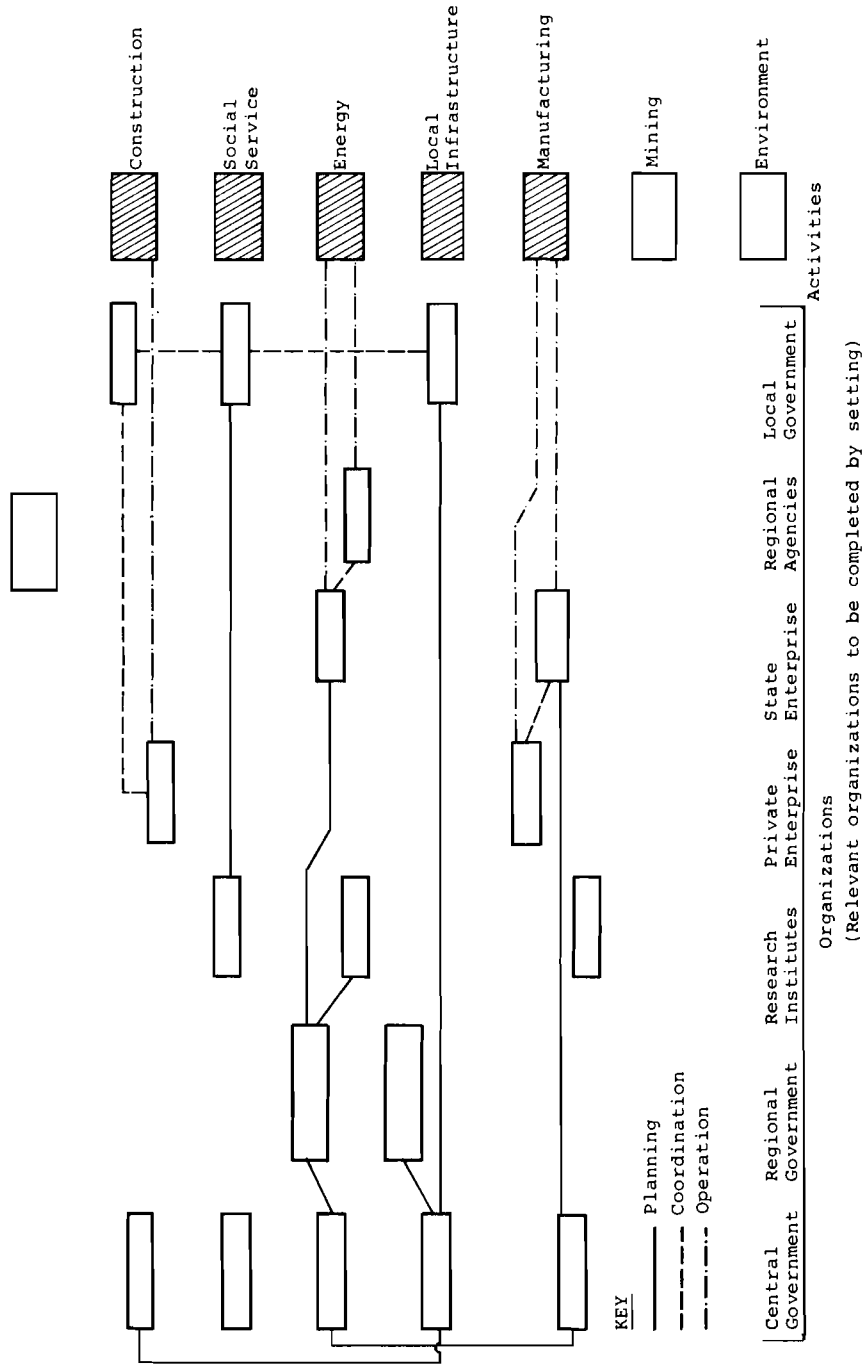


Figure 2. Illustration of composition of multiorganization
(diagram does not refer to the BITPC).

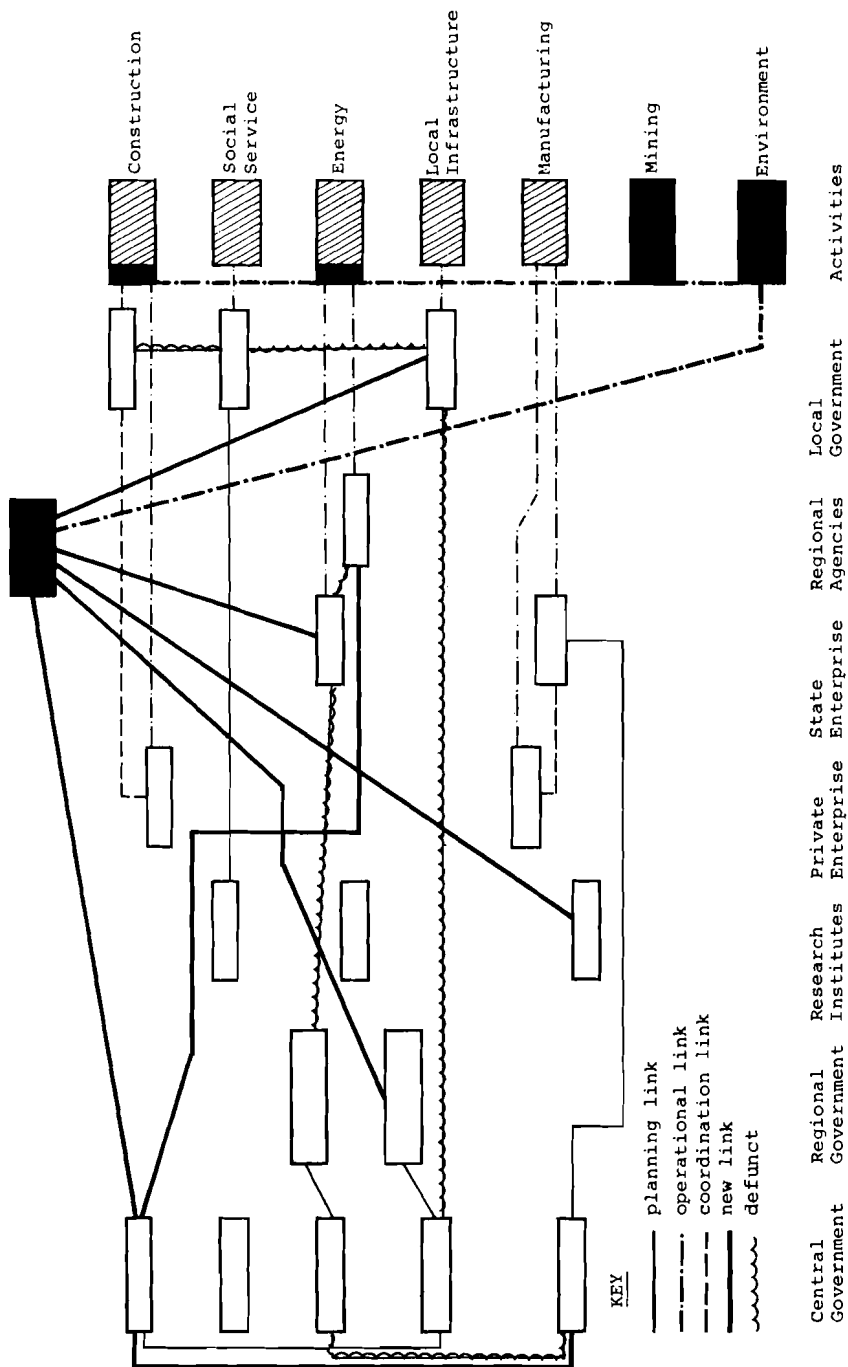


Figure 3. Multiorganization for regional development
(does not illustrate the BITPC).

to map the TPC boundaries within their own organizational structured, i.e. to create a level or organization to cover their operations just in the TPC. The clearest and probably most important example of this is in the construction area through the formation of Bratskgesstroi. In other areas, we are less clear: Table 1 gives our impressions from reading the papers. We would like comments whether the understanding presented in the Table is correct and generally on how important Soviet scientists consider this issue to be.

Table 1. Our Present Understanding of the Organizational Representations of Various Activities at the TPC Level.

Activity	Bratsk-Ilimsk
Administration	No (?)
Transportation	Yes (?)
Power Supply	No (?)
Construction	Yes (?)
Heavy industry	No (?)
Light industry	No (?)
Agriculture	No (?)
Environment production	No (?)
Recreation	No (?)
Research	No (?)

Integration of Plans of the BITPC Activity

We would expect that the requirements for integration of the plans of any regional development scheme go beyond those found in the normal operation of any planning system. From the description of the planning arrangements for the BITPC, it is clear that the potential does exist to achieve integration for the complex (Figure 4). Planning connections exist between all units at each horizontal level, and planning connections link the different levels. The degree of integration that can be achieved in practice, however, depends on the capacity of each of the planning links to carry information, and on the capacity to process that information at each level. Understandably, it had not proved possible in the Conference papers to provide the

degree of information that would allow an analysis of this, although one does get a feel for the magnitude of the task: "To work out plans for the development of the economy of the complex is a complicated and labor consuming process involving many units....".*

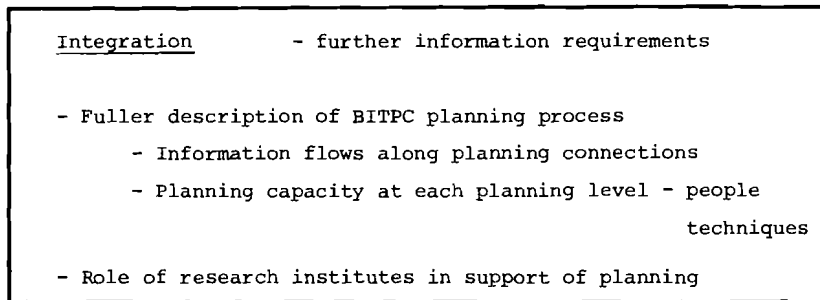


Figure 4

Despite the obvious complexity, we hope that our further discussions allow us to understand this process in some detail. In particular, we would like to have a fuller description of the BITPC planning process: a) information flows along planning connections, and b) the planning capacity at each planning level-- people and techniques. We would also like to know more about the role of research institutes in support of planning, and about how this is organized.

Coordination

Integrated regional development will in general imply a high level of coordination of ongoing activities, although the particular needs for coordination will differ from project to project. It is clear in the case of BITPC that particular coordinational needs arise through the rapid expansion of production and infrastructural facilities. This appears to have been an important reason for the creation of Bratskgesstroi in the early stages of the program. We would like to learn more about the role of this organization.

However, outside of the construction area we see other needs for coordination which are not discussed in the papers. We expect that the plans for the complex include manpower allocations between activities. In the case that the eventual manpower availability is less than the planned level, clarification of mechanisms for short-term reallocations would be helpful.

*See V. Gukov and N. Perevalov, *Management of the BITPC*, in this volume.

In supplying electricity to the region there may also be needs for coordination; in the event of a breakdown of generating capacity decisions have to be made on whose power demands are to be met. We would like to know the extent to which such problems occur and how they are solved.

Resolution of "Conflict of Objectives"*

Integrated development brings together activities which in other settings may have remained unconnected. Organizations have to operate under constraints which may be particular to the developed scheme. In any setting, therefore, the potential for increased conflict of objectives may arise.

In the case of BITPC we see new potential areas for conflict:

- Between sectorial and regional interests;
- Between different sectors in the process of increased coordination; and
- Between different territorial-administrative levels which the TPC falls into or itself includes.

Several mechanisms are suggested or implied in the Conference papers to meet these. They are:

- The use of the plan to give a legal expression to new, desired objectives, and behaviors;
- New formal rules or procedures for conflict resolution. Particularly apparent powers of veto by regional executives over some sectorial schemes;
- The power and influence of Bratskgesstroï as a single organization wholly identified with the TPC;
- The election of sectorial managers to regional committees;
- Positive individual behaviors motivated by a common concern of all elements to raise the living standards of the population of the TPC; and new economic mechanisms and incentives.

We would like some assessment from the Soviet scientists on the importance of each of these mechanisms (and any others we have missed) in the practice in eliminating or resolving conflict.

*The term "conflict of objectives" is translated from the Russian Razreshenie Raznaglasii.

Management Practices: Bratskgesstroi

The creation of Bratskgesstroi seems to have been a significant factor in the successful development of the TPC. Our understanding of the TPC would be helped by a fuller appreciation of how Bratskgesstroi operates, both internally and its links with many of the other units in the territory.

We have already been provided with an overall structure of Bratskgesstroi. We would like our further discussions to provide a fuller description of its internal capacity for coordination and integration; management control practices; its use of models and direct support from scientific institutes; and the type of inputs it receives from other units operating on the territory of the TPC. We understand that there are several different types of other units. There are enterprises directly subordinated to Union Ministries, to Republic Ministries and to the territorial Executive Committees. In addition, there are different configuration of units above the enterprise level. We would expect, therefore, that the objectives and responsibilities associated with each type will differ. To understand the particular ways each type of unit links with Bratskgesstroi, we should be aware of these differences.

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Implementation of a Long-Term Program for the
Development of the BITPC

G.M. Filshin

The following criteria have been applied in the development of the Bratsk-Ilimsk Territorial Production Complex (BITPC):

- Availability of abundant natural resources on a relatively restricted territory, making it possible to jointly use some major elements of the productive and social infrastructure (e.g., system of population settlement and transport links, common industrial base of construction;
- Knowledge of the territory and its natural endowment thereby ensuring a reliable evaluation of the economic feasibility of the resources and the expediency of joint development;
- A considerable national economic potential for developing the natural resources of the given territory and for providing the necessary material and human resources.

The idea of developing the most effective natural resources at the middle reaches of the Angara River was advanced back in the early 1930s, but conditions for its realization were not present until the end of the 1940s and the beginning of the 1950s.

The 19th Congress of the Communist Party of the Soviet Union set forth directives for the national economic development for the period 1951-1955. In accordance with these directives, the Hidroproekt Institute, jointly with other R&D and project planning organizations, worked out a hydropower project scheme for the Angara River to be realized by 1953.

The draft program envisaged the following:

- Helping the country meet its growing requirements for cheap electric power and for products of the chemical industry, the ferrous and nonferrous metallurgical industries and the timber processing and mining industries;
- Increasing the social productivity of labor through the development of unique natural resources of the Mid-Angara Regions, based on the use of modern technologies;

- Solving social and economic problems connected with attracting and settling manpower and the best possible use of available labor resources; and
- Transforming the BITPC into a potential support base for the development of new territories within the zone of influence of the planned Baikal-Amur and the North Siberian Railways.

Thus, the aims of the draft regional program virtually merged with the major national goals of improving the living standards of the Soviet people by raising the social productivity of labor on the basis of accelerated technological progress and the efficient location of the productive forces.

The draft program outlined the Complex's requirements for key resources of multisectorial importance, and mapped out ways for their rational use, identifying possible bottlenecks in implementation.

Despite the tentative nature of most estimates, it was obvious, even at that time, that the manpower shortage and the limited possibilities of having a sufficiently built up construction industry to meet the demands of the Complex would be the two major time-limiting factors in the program implementation. In this connection, the draft program envisaged the use of labor-saving technologies and a high level of mechanization, taking into account specific regional features with a view to and accelerating the development of a powerful building organization with the appropriate material and technical bases. In a special section of the draft program an attempt was made to synchronize the construction work and the commissioning of the capacities of allied industries and to work out an expedient schedule for concentrating material and financial resources on key projects.

However, some of the fundamental aspects of the program that defined the long-range strategy for the building of the territorial-production complex were not at this time elaborated thoroughly and consistently enough to ensure their practical realization. The probabilistic approach, which we believe is typical of such comprehensive regional programs based largely on stochastic regularities, was compounded in this case by the varying project planning standards for various industries.

Plans for hydropower construction were more thoroughly elaborated, and the priority assigned to hydropower engineering schemes was distinctly manifested in the draft documents and in the building of the Complex. Because of the rapid progress in the construction scheme, it was not always possible, at the initial stage of the program implementation, to ensure that the resource, social, and investment blocks be properly balanced. However, the experience gained in building the BITPC and in implementing the large-scale investment program has definite merit.

In a relatively short period of time (less than 20 years) and on a practically unsettled territory, capacities have been created for producing large quantities of cheap electric power, cellulose, high-quality aluminium, iron-ore concentrates, etc. The labor productivity per industrial worker of the BITPC is 2.5 times higher than the corresponding national average, and many technical schemes pioneered here are being successfully introduced at enterprises and construction sites in other regions of the country. While in operation, the Bratsk hydropower station (HPS) has generated about 250×10^9 kWh of electricity, saving more than 2×10^9 roubles, owing to cost differentials alone. Over this twenty year period new towns have been built on the territory of the Complex; there is a developed social infrastructure and the population exceeds 300,000. The building organizations of the Complex are capable of putting to use about 400 million roubles, which is equal to the annual capacity of four to five medium-sized industrial enterprises.

The economic potential created in the Mid-Angara Region substantial influences the rate and scope of development of nearby territories, and this influence will increase. Thus, the goals of the first stage in the realization of the comprehensive program have been achieved.

Of great scientific and practical interest are the ways these goals have been achieved and, in particular, the tendencies and principles of the realization of the construction program as revealed in the process of the Complex formation.

Let us first examine the general patterns in the creation of a district industrial construction base. During the 1956-1960 and the 1961-1965 five-year periods, capital investments in the industrial construction base averaged 9 percent of the total amount of construction and erection work carried out at the Complex; in 1966-1970, their share dropped to 4.5 percent, and in 1971-1975, it reached the standard level of the country's settled regions.

Naturally, during the first years of construction capital investments in the industrial base considerably exceeded the average indicators and increased, in absolute terms, two- or three-fold annually.

During the periods 1956-1960 and 1961-1965, as a result of the rate and scope of the formation of the industrial construction base, many major industrial projects were built at the Complex. This rate of development may be seen in both the distribution of capital investments among the key projects, and the average annual growth rate in the amount of work done on contract at various projects. The share of the Bratsk HPS in the total amount of work performed by the Bratskgesstroi in the 15 year period, 1956-1970, reached 33 percent. Work on constructing the Bratsk HPS was intensive in 1957-1961, when it represented over

70 percent of all contract work. The average annual growth rate of contract work in that five-year period was 32 percent. Once the first power units of the Bratsk HPS were operational, efforts were concentrated on constructing the Bratsk timber industrial complex. From 1961 to 1965, the construction of the complex claimed about 30 percent of all contract work, and the average annual growth rate of construction and erection work in this period was about 34 percent. From 1956, when the first section of the Bratsk timber industrial complex was operational, until the end of the eighth Five-Year Plan (1966-1970), more than 20 percent of all contract work went into the construction of the Bratsk aluminium works. During the last years of the eighth Five-Year Plan, work on constructing the aluminium plant accounted for over one-third of all the contract work being carried out by Bratskgesstroi. In 1965-1969, the average annual growth rate of contract work at the aluminium works project exceeded 40 percent.

One reason for these growth rates, given the long-range plans for implementing both the multibranch program and the regional development program, is the leading role played by Bratskgesstroi, whose main responsibility was to provide for the hydropower construction. Note should be taken of the very complex problems of simultaneously building large projects such as the Bratsk HPS, the timber industrial complex, and the aluminium plant. At the peak of the construction effort, there was a need for a building organization that would be able to carry out construction and erection work worth at least 250-300 million roubles a year. In addition, there was the parallel construction, on sites relatively remote from the central base, of the Korshunovo ore-dressing integrated plant (since 1958), and the Ust-Ilimsk HPS (since 1962), as well as the construction of the towns of Bratsk, Ust-Ilimsk, Zheleznogorsk, etc. It was therefore felt that the alternative to building the main projects consecutively was to create, at least toward the end of the 1956-1960 period, a material and technical construction base that would increase the organization's potential to annually perform construction and erection work worth at least 350-400 million roubles. The Bratskgesstroi reached this level in the second decade after the creation of the territorial-production complex.

It is noteworthy that during the ninth Five-Year Plan period capital investments and construction and erection work were distributed evenly among the main projects belonging to the various specialized branches. The share of the power engineering industry, the timber industry, and the ferrous and nonferrous metallurgical industries in the total amount of construction and erection work done at the Complex's projects amounted to 30, 28, and 20 percent respectively. The share of construction and erection work carried out at nonindustrial projects stabilized, and the building organization's potential increased. During the same period, the first stage of the Ust-Ilimsk HPS became operational ahead of schedule; construction of the second stage of the Bratsk timber industrial complex and of the aluminium plant was also completed.

Because of the development level of the construction base and the potential of the Bratskgesstroi, it was possible to carry out preparatory work on the building of the Boguchansk power station, the fourth in the Angara series, and other activities as indicated above.

Currently, one of the main tasks of the Bratskgesstroi is to further develop the material and technical construction base through the wider use of the most promising materials and structures (aluminium, polymer, plywood, etc.). For example, savings obtained by using aluminium rather than traditional materials at the construction sites of the TPC and nearby areas are estimated at about 3000 roubles per ton of aluminium.

In the long term, the expansion and modernization of the material and technical construction base of the BITPC should be more rigidly linked with the scheme for the further development of the industries and towns of the Complex. The proposals for the draft scheme provide for the comprehensive use of forest resources and mining raw materials (e.g. developing the Rudnogorsk iron-ore deposits, the Igirma deposits of quartzite sands, and the Zheronsk deposits of coal), and the development of the chemical and petrochemical industries on the basis of rich deposits of salt and potential reserves of hydrocarbonaceous raw materials. Provisions have also been made for making full use of the economic potential of the BITPC to develop the adjacent territories both to the East and to the West of the Complex. Thus, the increase in the economic potential of the Complex, including its building potential, is a powerful stimulus for the development of new natural resources on the territory of the TPC and in adjacent areas.

The creation of the Bratsk-Ilimsk Complex as a whole may be conditionally divided into three stages. The first stage (1955-1961) was marked by the concentrated effort to build the Bratsk HPS, to expand the industrial construction base, and to create engineering communications and settlements. From 1958, work was carried out in preparation for the construction of the Bratsk timber complex, and large-scale work began on building the Korshunovo iron-ore dressing integrated plant and the town of Zheleznogorsk.

The second stage (1961-1970) is characterized by concentrated efforts on erecting the first sections of the Bratsk timber industrial complex (1961-1965) and of the Bratsk aluminium plant (1965-1970). Since 1966, work has proceeded on constructing the the Ust-Ilimsk HPS. In the mid-1960s there was a sharp increase in the share of contractual work as a result of the construction of the town of Bratsk. In 1966-1967, the construction of Bratsk claimed more than one-sixth of the total amount of work carried out at the TPC projects.

The current period (1971-1975) is characterized by the rational combination of the consecutive and simultaneous

construction of the Complex's key industrial projects, and by the accelerated formation of the social infrastructure and industries forming the Complex.

During this period, the techno-economic indicators of the development of industry and construction in the TPC have greatly improved. By the end of the ninth Five-Year Plan, industrial output has increased ten-fold as compared to that in 1960, while the number of industrial personnel has grown only four-fold; output per rouble of fixed production assets has grown 3.5 times. The building industry yielded a 20 percent profit, whereas in 1960 many building organizations were operating at a loss.

Although the stepwise building of the BITPC may be viewed historically, we feel that some of the general principles have a general methodological and practical importance for territorial-production complexes of this type. In particular, in view of the established practice of combining sectorial and territorial planning, it is expedient to create district industrial construction bases simultaneously with the construction of one of the basic projects of the complex.

The experience of building the BITPC also suggests that at the initial stage the potential of the building organizations and their industrial base should be built up at an accelerated pace, and efforts should be taken to speed up the formation of the social infrastructure of the complex as a whole.

The main task of the second stage is to secure a rational sequence in the building of interrelated projects of the complex, for example to increase the capacity of the HPS and to build the aluminium plant, which is the main consumer of electricity. Optimally it is important that there be a rational distribution of efforts and a concentration of capacities, resources and funds on the most important projects.

Toward the beginning of the third stage, criteria were established for simultaneously building the TPC major projects in their most rational combination. It was during this period that practical ways were found for jointly and comprehensively using natural resources of intersectorial importance, and for solving certain urgent social tasks.

Analysis has shown that a timely elaboration of a comprehensive program ensuring the necessary balance among the resource, social, and investment blocks, would make it possible to reduce considerably the time needed for constructing the complex (especially during the first and second formation stages, and to increase markedly the effect of the entire program on the national economy.

The experience accumulated in building the BITPC reveals certain features common to investment programs for the development of new territories. These programs are part of regional

programs for the long-term development of natural resources in the areas of their highest concentration. The experience of long-term comprehensive regional planning for Siberia has shown that the pivot of such programs is a multisectorial production block (resource block) reflecting (through geological, surveying and project planning materials) the character and scope of the development of the natural resources of a given territory during the planned period. As a rule, the ultimate objective of comprehensive regional planning is the rational exploitation of certain combinations of natural resources.

A set of proposals for the pattern and scale of the development of natural resources worked out at the sectorial level forms the starting variant of the resource block. At the next stage of investigation, the aim is to determine the requirements of specialized enterprises in order to be able to supply the key resources of intersectorial importance (labor resources, construction and erection work, settlement and industrial territories, transport and engineering communications, etc.). At this stage, the temporal and spatial aspects of the comprehensive program are determined tentatively, and potential foci of intensive construction and centers of population settlement are identified.

During the first development stage of the resource block, calculations are made of the manpower requirements of specialized branches and the amount of construction and erection work needed for territorial and sectorial aspects, by year or by stage of the planned period. These provide information for the formation of the social and investment blocks or subprograms.

At the initial development stage of the social block--a subprogram based on the All-Union standards with due regard for respective stages of the planned period and the specific features of the region--indicators are obtained for the provision of non-productive resources for the region's population. Emphasis is on the adequate provision of non-mobile or insufficiently mobile resources, including social infrastructure projects and perishable foodstuffs and other consumer goods that are best produced on the spot and in adjacent areas. The data thus obtained make it possible to determine the manpower requirements and the productive sphere and branches servicing the population.

At the final phase of the first development stage of the social block, tentative estimates are made of the given region's general manpower requirements and the population growth rate according to the initial variant, with due consideration for the forecast family coefficients. The forecast of the size of the population and the planned indicators of the provision of non-mobile resources for nonproductive use make it possible to determine long-term requirements of the social block in construction and erection work by year or by stage of the planned period for the investment subprogram.

In addition to these indicators, data are collected on the resource block, and these data reveal, at a preliminary stage, the general requirements of the comprehensive program for construction services by year and by planned period. This information is needed for the investment block.

As a possible means for meeting some of the requirements of the comprehensive program for construction services, it is important to determine the capacities of building organizations and industrial construction bases located at reasonable distances within a larger territorial formation, say, an economic district. It is then possible to estimate the nature and scope of the development of the district (local) material and technical construction base and the potential of building organizations for carrying out the tasks of the comprehensive program.

The first stage of preparation of the comprehensive program is concluded with the detailed elaboration of the concept of the program and with the establishment of the criteria for evaluating the optimal use of these intersectorial resources that are in short supply.

Based on the above, a strategy is evolved for reaching the goals set, which is then taken into account in determining the economic and technical policy for the long run and for the main stages of the medium-term plans (the five-year plans).

At the second stage, optimal solutions are sought within each block or subprogram. Analysis is made of the requirements of the comprehensive program and the supply (actual and potential) of resources of intersectorial importance, with a need to ensure that the technical and economic decisions made by branch bodies are in line with the basic principles of the strategy evolved.

With regard to the investment block, the search for the optimal variants for implementing the construction program is conducted in two interconnected directions.

First, the most rational pattern is decided for the location of the central (district) industrial base and its branches in relation to the main centers of large-scale construction. At the same time, proposals are worked for the joint use of the main building organizations and their mobile units needed to relieve peak loads in remote areas with comparatively small amounts of construction and erection work.

Secondly, regional features are taken into account in making recommendations of a long-term nature concerning the choice of the most progressive material structure of the industrial construction base. Minimization of labor expenditures directly at the construction site may serve as a criterion here.

Capital investments in the productive base may be regarded as rational when they are no more than 10 percent of the planned

construction and erection work in the first medium-term period (five-year period), 5 to 6 percent in the next medium-term period, and reach the standard 2.5 to 3 percent over the more distant planned period.

The results obtained for the more realistic variants of implementing the construction program in terms of time and territory are supplied to the resource and social blocks for further adjustment and coordination. The mutual adjustment and subsequent coordination are carried out until the comprehensive program is completely balanced out, assuring, on the one hand, the realization of the ultimate goals of the program in fixed time-limits and, on the other hand, reflecting, directly or indirectly, the most important results of optimization within the blocks.

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Planning and Management of the Investment
And Construction Process

K.H. Schaffir

This paper seeks to establish a framework for discussing the management of investment and construction activities of the Bratsk-Ilmsk Territorial Production Complex.

Construction of facilities for power, transport, industrial production, habitation, and the provision of supporting services are major vehicles for regional development since they are the bases for employment and upgraded living standards. Where the supply of labor is a limiting factor (as was the case at the BITPC), construction activities must be well managed so as to achieve high output levels with a limited manpower input.

The management of the construction process requires critical decisions on allocation of the human, physical, and financial resources from outside the region, and on the disposition of transportable commodities and products available as a result of investment in the region.

SYSTEMS APPROACH

As systems scientists, we are concerned not only with *what* has been accomplished, but also with *how*, i.e., with the methods for selecting goals, formulating plans, organizing work, and dealing with uncertainties. The accomplishments of the BITPC are impressive in scope: the magnitude of the construction activity at its peak was about 300 to 400 million rubles (about half a billion US dollars) per year, and the major objectives were successfully realized. The intent here is not to question what was done. Rather we hope to derive some useful concepts or approaches that will benefit other comparable efforts now in process or to be undertaken in other regions. It is assumed that good results can be made better and poor results avoided by the systematic application of proper methods derived from an analysis of experience. We cannot in the space available explore these methods. We therefore will focus on a few aspects.

ORGANIZATIONAL ASPECTS OF REGIONAL DEVELOPMENT

Although this subject will be dealt with elsewhere in these Proceedings, some relevant points as to the investment area will be covered here.

A fundamental problem is the multiplicity of relationships of design and construction organizations, and other participating parties who may have different aims. These other participants may be broadly grouped into two categories. First, there are those who are external to the region but who play a major role in providing overall direction and resources. This group includes the national government and its ministries or departments, and, in a western environment such as the Tennessee Valley Authority, the financial interests in the private sector, regulatory agencies, special interest groups, etc. The second group includes those local, internal organizations who must participate in the development effort, contribute their resources and eventually interact with the new organizations and facilities.

The multiplicity of relationships is further complicated because design and construction activities involve both external and internal organizations. We are dealing with a multiorganization whose elements are interlinked by social, technical, and legal obligations, but whose individual objectives are different and often conflicting, particularly as regards the allocation of resources or benefits. These differences can sometimes be reconciled in the short term, but achieving an equitable balance requires consideration over a longer term, extending to 10 years and beyond.

ORGANIZING THE FLOW OF INFORMATION

From a point of view of the information flow, it is useful to differentiate within this multiorganization between those units whose role it is to design and make proposals, and those who review and accept or reject these. Proposals take the form of programs or projects such as the construction of hydroelectric facilities, aluminium plants, timber production complexes, and residential and transport facilities. Review and acceptance of such proposals is organized in terms of functions corresponding to areas of compliance of performance such as conformance to national production goals, to limitations of manpower or financial resources, to environmental standards, or to technical requirements of operation and construction.

These relationships can be represented in terms of a two-dimensional matrix (Figure 1). The design and planning dimension (or proposal dimension) defines the overall development program in terms of its component projects. For each of these projects, the review-acceptance dimension identifies the functional areas and corresponding organizational units whose involvement is necessary. The picture is somewhat complicated by the fact that a single function will involve several organizational units in a review and approval role, and a number of functions may need to be considered jointly or in relation to each other. This may be viewed as a third dimension in which approval or acceptance proceeds from lower to higher levels, although in fact such a sequence is not always observed and final approval from which

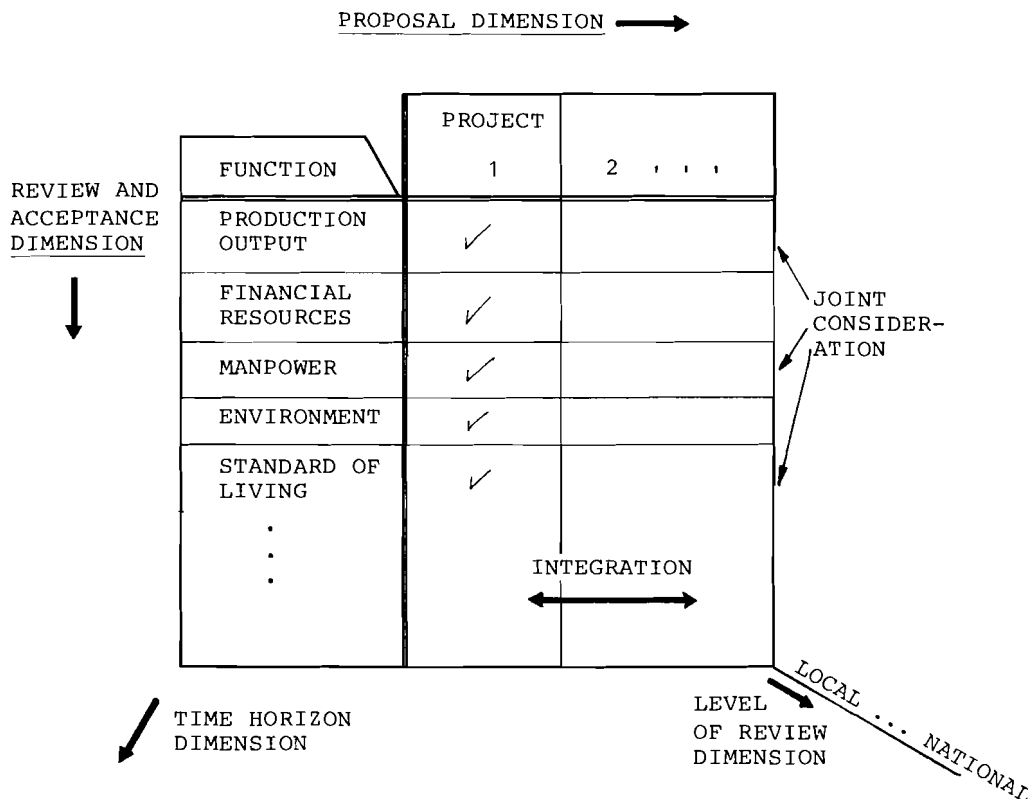


Figure 1. Proposals - acceptance relations.

action can proceed may occur at almost any level. Repeated cycling between levels and across functions may and generally does occur.

In particular, we can distinguish two major cycles that over-lap but serve two different purposes. The first cycle of proposals and reviews aims to establish a framework of objectives, policies, and criteria for preparing design proposals. We refer to this phase as the preparation of design specifications. The second cycle involves the design and proposal preparation.

The preparation of specifications tends to occur at higher or more central organizational levels, and requires functional coordination. The design process, on the other hand, centers on lower and more specialized units. Vertical communications permit specifications to be modified and to evolve as major

design alternatives that are defined and evaluated, and ultimately accepted.

Analyzing the information flow along these dimensions may be useful for clarifying responsibilities or roles to be taken by different units, for reducing redundancies, or for taking necessary steps to allow the overall process to proceed more quickly and effectively to a sound, optimal conclusion. The Lublin coal basin development project may present an opportunity to pursue this concept in an on-going context.

METHODS OF PLANNING

The principles of decision theory suggest that alternative goals, conditions, and lines of action are to be defined on a comparable and consistent basis, and the best selected on the basis of stated criteria. In practice, more often than not, only a single plan may be advanced, and this plan is then modified and "massaged" until it passes review and is accepted for action. Alternatives may only be informally considered as the plan evolves, but not actually defined completely or compared formally. The more formal approach is more demanding in terms of effort and time. In an undertaking of the magnitude of the BITPC and, in fact, any regional development effort, the magnitude of the planning effort is great, and a proper balance of formal and informal methods must be maintained so as to keep the total effort manageable and practical.

At the same time, one must take into consideration the possible advantage of the more formal approach for providing better assurances that all major aspects and functions receive full consideration, and that divergent views may be more fully exposed and more rationally reconciled so as to arrive at a superior final result.

In practical terms, it is not possible to compare and evaluate all alternatives simultaneously; or even to compare a limited number of alternatives with respect to all functions and criteria at the same time. Therefore, it is necessary to follow a sequential procedure. The author outlines such a sequence of steps in terms of major blocks. First, a *resource development block* is established and internally balanced with respect to intersectorial dependencies. Next, a *social block* is defined so as to provide support services consistent with the exigencies of the resource block. Lastly, a *construction investment block* is developed to permit realization of the requirements of both the resource block and the social block, with emphasis on optimal utilization of manpower, which is in short supply.

In this sequence, the first block serves to establish specifications for the second, and the first two blocks together establish specifications for the third.

It is not clear from this description to what extent it may be useful or feasible to re-examine the results of planning of the first block, and of the specifications on which it is based, in the light of information developed in the other two; or to develop alternative resource development specifications and designs which may be carried through the subsequent blocks in parallel. To do so may prove valuable because it would permit further examination of incremental effects in terms of their costs and benefits.

Questions may arise as to how far to carry the development of separate alternative sets of specifications or major variations so as to ensure that an ultimate selection be made on the basis of relatively complete information on major alternatives.

INTEGRATING INDIVIDUAL PROJECTS IN A COHESIVE PROGRAM

As the preceding sections have indicated, the planning and design process serves a dual purpose. At the technical level, it aims to formulate a program of action designed to accomplish specific objectives and to meet stated conditions or limitations. At the management level, it provides for the reconciliation of different views on objectives and on the conditions that must be met in those areas where conclusive answers cannot be reached on strictly technical grounds.

From a technical and managerial perspective, it is essential that plans be examined in relation to objectives at the level of the individual project, and also for the program as a whole. Filshin has raised this point with respect to the BITPC.*

In the context of the construction sector, for example, there is a need to determine the ultimate level of local construction forces in the light of the requirements of the major hydropower project that occurs at the outset, and the subsequent requirements of industrial and residential development. Important interrelationships among these projects exist not only with respect to manpower and construction facility requirements, but extend to a consideration of environmental consequences, requirements for habitational facilities, and financial resources. For example, the large investment in power generation will be recovered only when the aluminium and chemical industries that use this power have been established and are operational.

The difficulty lies in the complexity of interrelationships and in the large number of variables and factors involved. Computer-based methods that use data base maintenance techniques and mathematical methods for projecting and accumulating voluminous data elements should be explored.

*See G. Filshin, *Implementation of a Long-Term Investment Program for the Building of the BITPC*, in this volume.

This line of development would lead to the introduction of a multiobjective project integration system that would accumulate on computer files information about proposed projects and their projected impact on future time periods in terms of different objectives or acceptance functions to be considered. Appropriate information retrieval and report writing routines would extract projected results on a combined or accumulated basis. Eventually, this information base would be augmented with information on projections for existing activities in the region, so as to develop a complete, comprehensive picture.

The emphasis is first on having design units follow a systematic, disciplined approach to defining key data in relation to design specifications and programs, in consistent terms, by project, and relative to a set of functions. Secondly, it aims for use of computer facilities to store these key planning data in such a way that it is easier for both design and functional units to analyze needed information, at the required level of detail and, organized so as to facilitate comparison and evaluation.

This implies the need to incorporate in the computer system certain basic modeling capabilities to handle sequential restrictions (e.g., critical path or network techniques); projections, by year, over extended time periods; and summarization of results across projects, by year and by function.

This type of modeling is different from that used for national or regional economic planning purposes, in that the latter are not project oriented and are concerned basically with economic balances. The two model categories are complementary and together provide an effective planning and evaluation system complex.

In the development of large-scale, computer-based models, it is useful to follow a methodical, step-wise approach beginning first with the establishment of the required data and file structures, and using basic aggregation and accumulation techniques that permit the examination of major alternatives in an integrated fashion at an early stage. Refinements for incorporating search or optimization techniques may follow at a later stage. This approach is being explored for the Lublin project. In the case of the TVA, the possibility of comprehensive integrated planning, incorporating both governmental and private sector elements, was precluded by the fact that the TVA did not have sufficient access to information about plans of individual private enterprises active in the region. However, planning models on a more limited scale have been employed.

SUMMARY

The systematic structuring of the information flow in accordance with proposal-acceptance relationships, and the integration of project information through development of computer-based data

bases and accumulation techniques are necessary steps toward establishing a framework within which a more extensive application of the systems approach may be advanced.

In summary, we might raise three points for discussion not only with respect to the Bratsk experience, but also to other similar future undertakings.

- Is it logical or useful to establish organizational distinctions or groupings with regard to
 - Project versus functional responsibilities based on proposal/acceptance relationships,
 - Design specification versus design preparation responsibilities, with the provision of feedback between them,
 - Integration of diverse projects with respect to specific functions or clusters of related functions?
- How could information flows among the different units in a multiorganizational environment be clarified or simplified, and would the organizational distinctions identified above provide a useful basis for defining key information elements and assuring greater consistency and comparability of information?
- What might be the role of a mechanized or computerized information system in the integration of long-term, multiproject planning?

Summary Report on the Technical Session
On Planning, Management, and Organization of the BITPC

H. Knop

The session devoted considerable attention to the subjects of analyzing regional goals and strategy-setting processes, regional organization, and mathematical models and model systems for regional planning and management.

The Soviet delegation presented valuable information on how decisions are made for the BITPC. Informal group discussions were held at which the participants were informed about preparations for and operations of the BITPC, its management, planning and information systems, and the interaction between sectorial planning and management authorities, union Ministries and regional planning and decisionmaking authorities.

The role of Bratskgesstroi in establishing the BITPC and in adapting to the latest stage of intensive development was another topic of interest.

During the session it proved useful to elaborate IIASA's approach to the study of different socio-economic systems. The participants found it helpful to understand the role of the BITPC in the future development of other territorial production complexes in the USSR.

It was generally felt that the session provided an excellent opportunity to exchange ideas and views about the best ways to solve management and planning problems. It also helped to build a framework for the IIASA field study of the BITPC which will be carried out in Bratsk in June and July of this year.

Discussion

Among the major topics discussed were incentives for attracting manpower to the Bratsk Region, organizational and management aspects of territorial production complexes (TPCs) and, in particular, of the Bratsk-Ilimsk Complex, development strategies for the BITPC, and problems of transporting raw materials and energy from the Bratsk region. A summary of the participants' comments on these subjects is given below.

A major management consideration of the BITPC is the provision of high quality social opportunities for the workers of the enterprises. Effects are made to ensure that the living conditions equal or surpass those available in the European part of the Soviet Union. During the initial development period of the BITPC, it was impossible to offer the physical and social amenities that are currently available. Nevertheless, much progress has taken place in this area mainly as a result of the emotional and patriotic motivations of the workers.

Advanced scientific and technological techniques are being applied to enterprises within the Complex, thereby improving the technological expertise of the workers. In addition, there are special training programs and schools for updating and upgrading their skills. The social infrastructure is being expanded to provide improved living conditions, health services, and cultural facilities. In addition, material incentives have been established. Basic wages are 40 percent higher in the BITPC than in other regions of the Soviet Union, and are increased annually by 10 percent up to a maximum of five years. Workers have 12 additional leave days over the norm and receive free transportation for vacation purposes to any part of the Soviet Union.

The management goals of the BITPC are based on the overall needs of the Soviet national economy. The planning process is goal-orientated and details are set forth on the goals, tasks, and directions of the socio-economic development. Some specifications exist dealing with the goal of improving the standard of living in terms of indicators of real income and consumption.

The strategy for developing the BITPC is directly related to the needs of the national economy. The idea of establishing TPCs dates back to the first Five-Year Plan. In the beginning of the 1930s, plans were being considered for developing hydropower facilities and simultaneously constructing energy-intensive industries.

Construction of the major facilities of the BITPC is almost completed. The current phase is that of intensive development, with a view to achieving a higher level of efficiency and production quality. Efforts are being made to improve the use of available materials, and to increase labor productivity. In the

period 1961-1965, manpower increased 22 percent; projections for the period 1976-1980 indicate only a 4 percent increase. This implies that up to 90 percent of the desired increase in production will come from increased productivity. Similarly in terms of investments, it is anticipated that the yield per rouble will increase.

Decisions on capital investments are based on proposals from local and central organizations. Decisions involving large capital investments are made at the highest national level; those dealing with smaller investments are handled by the appropriate body according to the size of the request. Apart from the national economy, other sources of investments are available, such as local funds, enterprise profits, and bank credits.

The Soviet Union is participating with other nations in the construction of new large organizations projects. In 1973, construction began on a new cellulose complex in Siberia that takes into account three major characteristics of the Siberian Region: the availability of large amounts of fresh water; the unlimited supply of raw materials; and the existence of the construction enterprise Bratskgesstroi. The other countries participating in the development of this project are Bulgaria, German Democratic Republic, Hungary, Poland, and Rumania. Each of the countries makes a certain contribution to the project, and will receive cellulose in proportion to its initial contribution. The plant is scheduled for commission in 1979, and it is anticipated that by 1991 all investors will have received a return on their initial investment.

In addition to new construction projects, intensive development of the existing industrial base of the BITPC is expected. For example, in the timber industries, new improvements are planned which will allow for a more efficient recycling of waste materials into cardboard production. The operations of Bratskgesstroi, will be updated and strengthened to adjust to these new requirements. An automated control system will be introduced in the aluminum plant. During this period capital investments are expected to increase by 40-50 percent.

To ensure implementation of the development plans for the BITPC, a Board of Directors was established, composed of the General Director of the timber production complex, the Director of the Bratsk hydropower station, the Director of the aluminum plant, the Director of the heating equipment plant, the Director of the polytechnical institute, and the Director of Bratskgesstroi; additional members serve as necessary. The Board's tasks are determined in the light of the needs of the Complex.

The overall management of the TPCs in the Soviet Union is currently under serious discussion. No one solution appears to be ideal, mainly because of the differences of the various TPCs.

In all cases of TPC development, the natural environment plays a prominent role. Attention is focused on optimal use of

natural resources and on preservation and protection of the environment. All-Union standards are in effect throughout the Soviet Union, and enterprise designs and regional layout schemes must include provision for effective pollution control. Monitoring agencies and local citizen groups are actively involved in ensuring that environmental considerations are included in the planning process and in the actual operation of individual enterprises.

The BITPC has proved the efficacy of establishing large TPCs, and the experience gained over the past thirty years is being applied to new TPCs.

**ENERGY SYSTEMS AND WATER
RESOURCE PROBLEMS**

Introduction

A.A. Makarov

This Conference focuses on the development and management of the Bratsk-Ilmsk Territorial Production Complex (BITPC). The energy supply problems of this and other regional complexes cannot be solved independently from the technological or sectorial principles which are of major importance to the Soviet economy. Thus, the planning of all aspects of energy production and consumption is carried out within the framework of a unified energy supply system (ESS).

The massive and rapidly expanding ESS of the Soviet Union produces more than 20 percent of the world's supply of energy, and the country leads worldwide in the extraction of oil, coal, and peat, and in the centralized production of heat and power; it is second in the production and consumption of the remaining forms of fuel and energy.

Planning for the ESS takes into account sectorial and territorial factors. The system is first divided into five energy-supply branches: petroleum, oil refining, gas and coal industries, electric energy, and heat-energy industries. Each of these branches is subdivided according to its territorial aspects--oil/gas regions, oil refineries, coal basins, and electric energy systems. The total of these respective systems within the framework of a given region forms a energy supply complex.

The largest regional energy supply complex of the USSR is located in Siberia. The Region contains the largest oil and natural gas reserves of the Soviet Union; moreover, a large unified power system is being developed which will supply electricity to the European part of the country by using direct current transmission lines with a capacity of 12 and 40 million kW. The central regions of Siberia, which include the BITPC, have specific conditions for the supply of energy that are reflected in the industrial structure of the complex.

Owing to Siberia's vast coal and hydropower resources, the cost of thermal and hydroelectric production is two or three times less than that in the European part of the USSR. However, the cost of high quality fuels (e.g. gas and fuel oil) is about the same as that in the European part. The reason is that major deposits of these fuels are located in the northwestern part of Siberia while the "consumers" are located in central Siberia. Thus in Siberia there is a large gap between the cost

of high quality fuels, and low quality fuel and hydropower capability. This gap is characteristic of the energy industry of other industrially developed countries after the 1973 energy crisis. The tendency to such cost differentiations will likely appear to some extent in the European part of the USSR.

Lower cost for electric energy production and the low cost of fuel for centralized heating supplies are two factors that have underscored the importance of locating power-intensive industries in Central Siberia and in particular in the BITPC. The large gap between the cost of high quality fuels and that of hydroelectric production has led to the increase in the electrification of heavy and consumer service industries in Siberia.

In Siberia the predominance of electric-energy-consuming industries and the Region's increased electrification of heavy and consumer-service industries has stimulated the dynamic growth of electric energy consumption as compared with other regions of the Soviet Union. This is in line with the increase in the production of electricity and the transmission of power to the European part of the USSR. In this connection, the choice of an optimal ratio for the different methods for producing electricity has great significance.

For example, the large difference in the cost of high quality fuels as compared to that of coal has resulted in the use of a combined scheme for supplying consumers with electricity--that is, using power plants to provide both heat and electricity. This increases the efficiency coefficient of the power plants from 40-42 percent to 60-70 percent. Figure 1 illustrates that the combined scheme is economically justifiable. The heat load is lower in Siberia than in the European part of the USSR.

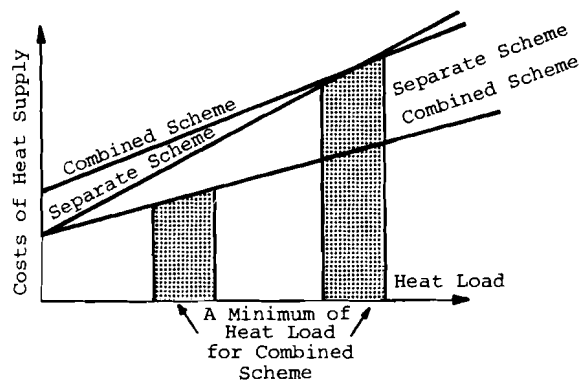


Figure 1. Combined and separate schemes for the supply of heat.

Table 1. Comparison of HPSS in the European and the Siberian Hydropower Systems.

EUROPEAN HYDROELECTRIC POWER STATIONS				SIBERIAN HYDROELECTRIC POWER STATIONS			
NAME	CAPA- CITY MW	C O S T S		NAME	CAPA- CITY MW	C O S T S	
		CAPITAL, ROUBLE PER kW	PRICE, ROUBLE PER MWh			CAPITAL, ROUBLE PER kW	PRICE, ROUBLE PER MWh
WOLGA-I	2300	300	1.0	BRATSK	4100	144	0.53
WOLGA-2	2541	220	1.0	UST-ILIMSK	4320	115	0.62
WOTINSK	1000	134	1.0	KRASNOYARSK	6000	98	0.79
KREMINCHUG	625	332	1.3	SAYANY	6400	100	0.5

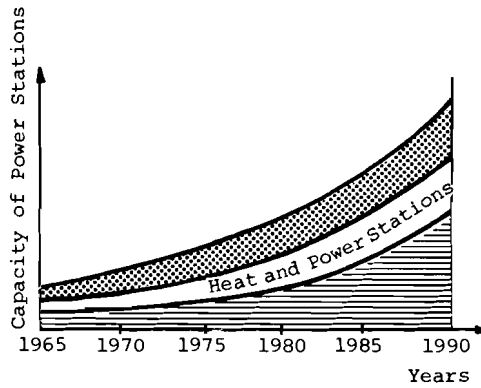


Figure 2. Structure of the Siberia Power System.

Because of the efficiency of the combined scheme and the many heat-consuming industries in Siberia, there has been accelerated development of heat and power plants, and a strengthening of their role in the production of electricity.

Another major characteristic of the production of electricity in Siberia is the importance of hydroelectric stations; currently they produce about one-half the total capacity of the Siberian Power System. Table 1 gives data on capacity and cost of hydropower stations (HPSs) in the Siberia Power System and in the European part of the USSR. All the HPSs listed were constructed at about the same time period. The table shows that the Siberian HPSs have greater capacities and lower costs than those in the European system.

Figure 2 shows the current situation of the generating capacities of the Siberia Power System, and its projected development. The current structure of the Siberia Power System provides for the optimal economic use of energy resources. The increased efficiency of HPSs and heating/power plants has resulted in a minimum loss of energy for the organic fuels that are converted into electric energy. In the future, however, it will be necessary to accelerate the construction of thermal power plants in view of the gradual use of hydropower capacity and the need to transmit large amounts of electricity to the European part of the USSR.

Mathematical Models for Optimizing the Development
Of Integrated Electric Power Systems in Siberia

L.S. Belyaev, A.A. Papin, and A.N. Zeiliger

Optimization of the development of an electric power system (EPS) consists in selecting the patterns and priorities for developing power installations (power stations and transmission lines). This choice must be made so as to provide an uninterrupted supply of power in the required amount at a minimum cost. The problem cannot be solved in one move since the calculations would be rather unwieldy and decisions have to be taken at different times in advance, with different degrees of uncertainty in the initial information for the different power units being developed. A hierarchy of problems has therefore to be elaborated.

Current views on planning the development of an EPS suggest that the sequence of problems to be solved is as follows [1,2]:

- Determining the long-term pattern of the generating capacities of an integrated electric power system (IEPS) in terms of fuels;
- Optimizing the pattern of generating capacities in an IEPS in terms of generating equipment, circuits and carrying capacities of power transmission lines linking one IEPS to another;
- Selecting the first power station to be developed and determining the development pattern of the core grid of an IEPS in the near future;
- Fixing dates for the commissioning of power stations, transmission lines, and plants.

The Siberian IEPS, which comprises the Bratsk and the Ust-Ilimsk hydropower stations (HPSS), has distinct technical and economic problems from other IEPSS in the Soviet Union. Siberia has enormous deposits of oil, gas and coal, and more than 30 percent of the country's potential hydropower resources. The choice of fuel for the new thermal power stations in Siberia is virtually dictated by the low cost of the brown coals of the Kansk-Achinsk basin, and the need for transporting the high-quality fuel of West Siberian gas and oil fields to the European part of the USSR. So, determination of the scale of construction of new coal power stations and HPSS is the key to optimizing the development of the Siberian IEPSS.

Since fuel is generally in short supply in the European part of the country, the Kansk-Achinsk coals may have to be added to its fuel balance in the future. But since it would be difficult to transport these coals over long distances, it would be profitable to burn them where they are mined and transmit the electric power produced through the grid. The optimal volume of this transmission is another major question in the long-term planning for the Siberian IEPS development. It is linked with the previous one and has to be considered within the overall framework of the country's fuel and energy economics.

Low costs of electricity production from cheap brown coals and the highly efficient use of hydropower resources of the Angara and the Yenisei Rivers favor locating power-consuming industries in Siberia. With industrial consumers taking a big share, power consumption regimes have to be very tightly organized. Owing to the high efficiency of the Angara-Yenisei HPSSs, their speedy construction has become a feasible and profitable project. So much so that at the moment the HPSSs account for 45 percent of the total output in the Siberian IEPS. They cope with fluctuations in the daily demand and are the main emergency reserve. In fact, no other variable-output power stations are needed in the Siberian IEPS.

The Siberian HPSSs could be expanded to cover peak loads and provide emergency reserves for other IEPSSs in the East and in the European part of the USSR. High-capacity links between the systems would have to be built for this purpose. In addition to an enhanced use of the Angara-Yenisei HPSSs, other factors contribute to the usefulness of these links. For instance, they promote cheaper and better use of the installed capacities in the Integrated National Electric Power System (INEPS) because of different peak load times at IEPSSs situated in different time zones, mutual standby possibilities, etc. Thus, the Siberian IEPS should be treated in a common framework with the other components of the INEPS.

The choice of an optimum pattern of capacities for the Siberian IEPS is largely affected by the fact that HPSSs play a major role and there are long-period storage reservoirs in the Angara-Yenisei cascade compensating for the random nature of the river flow. The problem is a probabilistic one.

A rational choice of the unit capacity and pattern of power blocks for the power stations of the Kansk-Achinsk Complex is vital for the Siberian IEPS. Plants of 800 MW capacity are envisaged for the first period. Later they will be larger (up to 1200-1600 MW) to boost labor efficiency, to save capital investment, and to speed commissioning times for putting new plants into operation. A limiting factor here is the difficulty of designing reliable high-capacity single-hull steam generators fueled with low grade coal.

Central heating and power plants (CHPPs) constitute a considerable part (30-40 percent) of the generating capacities of the Siberian IEPS. Choosing an efficient scale of development for them involves certain considerations. In particular, combined heat and power production at CHPPs with cheap coal is more efficient than from boiler houses operating on more expensive liquid fuel. Also the condensation portion of CHPP capacity is normally used to cover peak loads of the system, but since in Siberia the variable part of the load schedule is met by HPSS, thermal stations (including CHPPs) operate only in their basic mode.

The territory currently served by the power stations of the Siberia IEPS stretches over vast areas from west to east, but the production capacities, e.g. the EPS, are heavily concentrated so that the overall pattern of the distribution of power production and consumption is extremely irregular. This results in a chain-type basic power grid for the Siberian IEPS, with long distances between the nodes and limited carrying capacities of the links. If a reliable supply of power to the consumers and a steady operation of the generators are to be ensured in the long run, major capital investment will have to be made on development of intersystem links. And it is as important to optimize the development of the basic power grids in the Siberian IEPS so as to solve the problems of structural design.

In the next 10 to 15 years, the Siberian IEPS will be integrated with the power systems of Kazakhstan, Central Asia, and the European part of the country. Moreover, with the building of the main line of the Baikal-Amur Railway, it will be possible to link it up with the Far East IEPS. The Siberian IEPS will then function as the middle link, so that its development must be closely coordinated with that of other power systems and with the formation of the INEPS.

Mathematical models have been increasingly applied to these problems of planning the development of the Siberian IEPS, and we shall now outline these applications.

APPLICATION OF MATHEMATICAL MODELS FOR OPTIMIZING THE DEVELOPMENT OF THE SIBERIAN IEPS

First attempts at using mathematical models to plan the development of the Siberian IEPS were made in the mid-1960s. At that time calculations were carried out for optimizing the structure of the Siberian IEPS with the use of a linear dynamic model developed at the Siberian Power Institute (SPI), with the assistance of the staff of the Northwestern Division of the Energosetiproekt Institute [3]. The problem was to find the most efficient proportions of hydroelectric and condensation-electric power plant development for securing the necessary pace of building up the system capacity between 1971 and 1975, and to determine the distribution of the capacity among the grid nodes and the links between them.

We have already mentioned that under Siberian conditions this is a stochastic problem that is not easy to solve now or in the foreseeable future. So its solution is broken down into two steps. The first is calculation of the water flow regulation to determine the hydropower indexes of the HPS cascade--i.e. guaranteed output during unfavorable hydrological conditions and average long-term power output. The second is determination of the optimum set of priorities and dates for commissioning the HPSs and thermal stations, with due consideration for these HPS indexes and for details of the power system development plans.

The period covered by the calculation was 12 years, in order to enable the HPSs to achieve full capacity. It was broken up into six two-year periods. The unknowns in the model were the capacities of the power stations at the nodes, and the carrying capacities of the links between them, estimated for the end of each two-year period. The functional of the model was the reduced cost of IEPS development for the whole period. The restraints were the capacity and the power balances at the ends of the time periods, fuel consumption rates, carrying capacities of the power transmission lines (PTL), electric power supply requirements, the dates of commission of the HPS peak capacities, etc. A modified simplex method was used in optimization.

A number of major conclusions were reached about efficient ways of developing the Siberian IEPS, and later these were borne out in practice. In particular, a dependence was found between the dates of commissioning the HPSs and possible development rates of thermal stations' capacities; it was found advisable to slow down the rate of introducing HPSs and to accelerate the building of thermal stations.

An integral part of determining the best long-term development plan for the Siberian IEPS was the calculation to optimize the national fuel and power balance (FPB), carried out in 1971 by using a linear model of FPB developed at SPI [4]. In the model, the Siberian IEPS was treated as a component of the INEPS. The model also sought to optimize the development of the fuel (oil, gas and coal) industries and of nuclear power engineering. The model was a static one and calculations were carried out for two dates, 1985 and 1990, with the optimum FPB obtained for 1985 being taken as the initial data for computing for the second date. Because of the uncertainty in the information for this long period, more than 100 computation alternatives were calculated varying the oil and gas resources, development scales of nuclear power plants and of the Kansk-Achinsk coal basin, fuel and power needs, etc. The computer programs used were based on a modified version of the simplex method.

The linear model gave the following information for developing the Siberian IEPS up to 1990:

- The optimum scale for constructing condensation-electric power stations operating on Kansk-Achinsk coals,

taking into account the conditions of fuel supply in various parts of the country, the comparative costs of transporting fuel and energy, and the location of power-consuming industries; and

- The regions of optimum use of power flows from Siberia and the time schedule of construction of direct current PTL.

Currently the SPI and the Energosetiproekt are determining the economic efficiency and priorities for integrating the EPS in the East, linking it with the European section of the national system. A recently developed linear mathematical model of an INEPS is being used for these investigations [5]. The objectives of the project are: estimating useful scales for exploiting the intersystem integration; investigating the effect of extending the range of Siberian HPSs to other IEPSS in the East and the European sections of the INEPS, with a view to fuller use of the former's capacities; and estimating the necessary carrying capacities of the intersystem links, their optimum operation conditions, and construction priorities.

A static version of the model is being used. The optimum criterion is minimum cost of construction and operation of various types of generating plants and intersystem links for the INEPS as a whole. The set of basic equations of the model includes: balances of capacity for combined maximum load of the INEPS and the particular IEPSS maxima; power balances with due regard for the intersystem PTL; restraints on the use of various fuels; restraints on admissible development scales of power stations and PTL; and operation modes of the power stations and PTL in daily terms.

When these problems are solved, it will be possible to give practical recommendations on the future role of the Siberian IEPSS in meeting the INEPS balance and to answer certain major questions of INEPS design.

Optimization of basic power grid development is important in the development of the Siberian IEPSS. The discrete nonlinear model [6] elaborated at the Irkutsk Polytechnical Institute has been used for solving this problem.

The power grid was represented in the model by means of a connected graph whose nodes are power generation and consumption centers, and whose branches are transmission lines and transformer substations. In all, 25 nodes and 48 branches, including 36 under design were considered. The aim function expressed the construction and operation costs of the power transmission lines, substations and the cost of energy losses in the period under consideration. These are a nonlinear nonconvex function of the sought after values and therefore, the problem is a multi-extremum one. The method used to solve it was to search for a local optimum on the basis of group relaxation methods. Additional difficulties

arise when the power grid is analyzed in dynamic perspective with all restraints, estimation of the reliability of power supply to the consumers, etc.

Some practical recommendations for efficiently developing the Siberian IEPS power grid have been formulated and submitted to the designing organizations. One important finding was the desirability of building 1150 kV transmission lines in this area.

Calculations on long-term operation schedules for the Siberian IEPS up to 1980 deserve to be mentioned among studies on its optimum development, the purpose being to assess the capacity and power balances of the individual IEPS nodes for putting new capacities into operation.

Two mathematical models that were developed at the SPI have been used in these calculations. The first model is for optimizing long-term operation schedules of the EPS including some HPSSs [7], and the second model is for optimizing future daily operation schedules. Both models treated the optimization of long-term operation schedules of the EPS as a nonlinear programming problem where some parameters may be discrete. The auxiliary functions methods were used for optimization in combination with the coordinate descent method. The EPS under study is represented as a set of nodes connected by power transmission lines. Various types of power stations may be present at each node.

From the first model, the outputs for the years under study were estimated for all Siberian HPSSs, and the water flow regulation schedules were determined. The second model gave the capacities of HPSSs and thermal power stations to meet typical daily loads and surges in transmission lines. Long-term capacity and power balances have been compiled from the results, and programs for commissioning power stations and transmission lines have been set up.

A FUTURE SYSTEM OF MATHEMATICAL MODELS

It is clear that vast experience has been accumulated in the use of mathematical models for planning the development of the Siberian IEPS: the initial phase of automating EPS planning and designing is complete.

Recently efforts have been directed toward creating an automated information system (AIS) for EPS designing [5]. Compared with existing systems and programs, basic improvements are envisaged for the structure of an AIS, namely: due allowance for the uncertainty in input data; development of an integrated data base; design of an AIS for solving all problems involved in EPS development; and development of automated sets of programs for solving similar problems.

Particular importance is attached to the first of these so that it will be possible to take more substantiated decisions and to reduce excessive costs caused by inexact knowledge of the system's future development.

The AIS for EPS design will comprise two types of interconnected design systems corresponding to two hierarchical levels of the real systems--the INEPS and the IEPS. Each level will have its own set of problems. The following distribution of tasks is envisaged for the AIS for the INEPS and the AIS for the IEPS.

The AIS for the INEPS will be concerned with the following:

- Estimating the system efficiency and the usefulness of creating new types of basic generating and electrical engineering plants;
- Selecting an efficient future INEPS pattern in terms of power station and generating plant types;
- Choosing ways of developing the basic grid of INEPS (configuration, voltages, carrying capacities of the intersystem PTL) for different periods of time;
- Determining a scheme for the near future and fixing dates for commissioning individual intersystem PTL; and
- Coordinating decisions on the development of power stations and PTL in the individual IEPSs, from the point of view of the INEPS.

The AIS for the IEPS will do the following:

- Determine the set of efficient development alternatives for future IEPS power stations;
- Set priorities for power stations to be constructed immediately after the completion of current projects;
- Choose development trends for the basic grids of the IEPS for different time scales; and
- Choose a scheme for IEPS grids for the immediate future and fix the time for building top priority PTL.

Also, the optimum scope for heat production and development of heating and power plants, etc. should be determined at this level.

For all problems associated with the optimization of the pattern of generating capacities, the external links of the EPS with other component systems of the national fuel and power

complex (FPC) have to be considered. For this, the development of the INEPS and its component IEPS must be first optimized within the more general framework of the FPC [4]. Such preliminary calculations provide the groundwork for decisions about the development of fuel industries, the amount of power resources to be allocated to electric power stations, and also the optimal patterns of generating capacities in terms of the main types of power station (peak load, semi-peak load, and base stations) for the INEPS and for the individual IEPS.

The problems to be tackled by the AIS for EPS design determine both the software package and the programs and data bases. Some software sets have already been determined [5] and are briefly described below.

The core of the software for determining an efficient INEPS pattern in terms of power station and generating plant types is a linear optimization model representing the INEPS as a sectorial system. This model has been outlined earlier, so we shall mention only a few additional details. Besides the optimization pattern of INEPS generating capacities, the model enables us to select the required carrying capacities of the intersystem links. It incorporates the determination of daily schedules for using the generating capacities and the intersystem PTL within a common time frame; the selection of the carrying capacity of the PTL, taking into consideration the intersystem effects (reduced emergency reserves, different timings of load peaks, etc.) and the distribution of reserve capacities among the nodes; a fuller account of the special features of the development and functioning of power stations, taking into consideration their individual types, etc.

Apart from the model, the computational software includes the data bank and a series of interlinked functional or ancillary programs, such as the supervisor, the data inputter and processor, the output routine, etc.

Programs and data bases for studying the system efficiency of power units comprises a dynamic discrete simulation model, which enables the dynamic balance of a system's capacity to be computed with given priorities for building power stations and commissioning their individual plants. The capital investments and the fuel costs of the system are evaluated by optimizing the operation schedules of the plant for a series of typical 24-hour periods which includes specifying the composition of the plant units to be used. At the same time the costs of developing and organizing the manufacture of new equipment are computed together with changed PTL costs and additional costs associated with eventual impact on the environment. The software package was built up from experience gained in using the early version of the dynamic discrete simulation model developed in 1969 [8].

The computational software package for problems of power station development at the IEPS level is intended for solving

certain problems. The package has a modular structure, each module being available in several modifications so that a variety of software operation modes can be organized. For optimum calculations, simpler module versions are used, while modules accounting for more details of the system's power and economic characteristics are applied to assess different alternatives.

The main modules of the package are: the balance module, which is intended to assess the dates for the commissioning of power stations, given their order of priority; the scheduling module, which optimizes the operation schedules of the power stations, PTL and fuel costs estimates; the PTL module, which evaluates the costs in terms of power grids for alternative variants of commissioning power stations and locating them in IEPS nodes; and the optimization module, which organizes the optimization process; it is based on the competition method [9].

Each module is an autonomous model having its own data files and fixed formats of input and output data. A special executive routine is used to operate this software package.

The computation program package for technico-economic calculations of the basic power grids of the IEPS is intended for solving network problems [10]. It comprises modules of main and operator programs as well as a data base. The program package includes the executive routine, the routine for formatting the data base, the routine for preparing the computing operation, and the module of main operating programs. The latter consists of optimization programs which choose the optimum configuration of a power grid by means of an algorithm of optimization by coordinates [11]; an estimation program for assessing the techno-economic merit of different configurations designed for the power grid; and an optimization program based on dynamic programming principles and some heuristic algorithms [12].

The package is already in use in some departments of the Energosetiproekt Institute.

The software sets listed above are standard tools for computational research used in optimizing the development of various territorial subunits of the INEPS, one of which is the Siberian IEPS. The problems of Siberian IEPS development that necessitate consideration of the system's relations with other power systems will be tackled within the framework of the AIS for the INEPS. A special AIS with its own mathematical models for Siberian IEPS design will be developed to deal with "internal" problems of the development of power stations and power grids in Siberia.

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Indirect Expense Accounting in Planning
Siberian Fuel-Power Resource Development†

Yu.D. Kononov

INTRODUCTION

Belyaev, et al. have shown that the major problems of developing the energy economy both at the BITPC and for Siberia as a whole must be solved by the optimization of the national fuel and power balance. The development of Siberian energy resources for meeting the country's demands requires large-scale capital investments and the increased output of materials and equipment for the oil, gas, and coal industries. This in turn creates the need for capital investments for energy-related industries (e.g., ferrous and non-ferrous metallurgical industries); we will call these investments (expenses) *indirect*. Several questions arise in this connection. Are the indirect investments and expenses for other limited resources essential? Are there variants that must be taken into account when determining the economic efficiency of Siberian energy development? If so, what are these?

These questions are of particular concern to the IIASA Energy Project which is involved in determining strategies for a transition from fossil to nuclear fuels.

THE NEED FOR INDIRECT EXPENSES

Interindustrial dynamic models can be used for monitoring the development of energy-related industries and the concomitant resource use. Such models have been used by the Siberian Power Institute for comparing variants of energy economy development in the USSR. These variants differ in degree of individual Siberian energy resource use.

Analyses have shown that the indirect expenses depend on the rates of involving capital-intensive energy resources in the country's fuel-power balance. If the rates are stable and low, then there is no need for a significant increase in the productive capacities of the energy-related industries; where there is growth in the rates of energy resource production, the capacities of these related industries is insufficient, thereby making it necessary to develop other related industries. The more abruptly the rates

†Comment on L.S. Belyaev, et al., *Mathematical Models for Optimizing the Development of Integrated Electric Power Systems in Siberia*, in this volume.

of energy development increase, the wider the circle of related industries and the higher the indirect material manpower, and money expenses per unit of energy resource (see Figures 1-3).

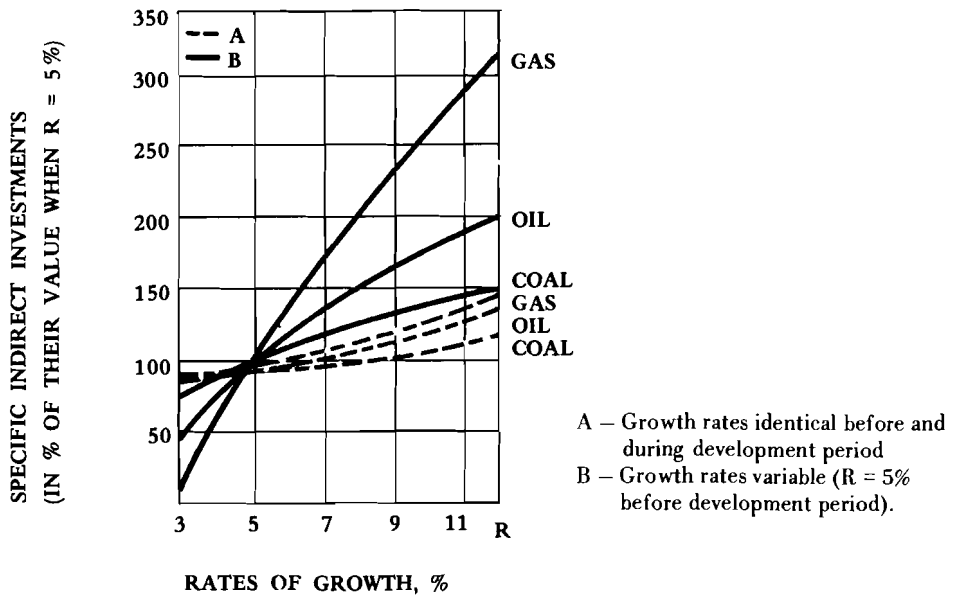


Figure 1. Dependence of indirect capital investment on growth rates of fuel mining.

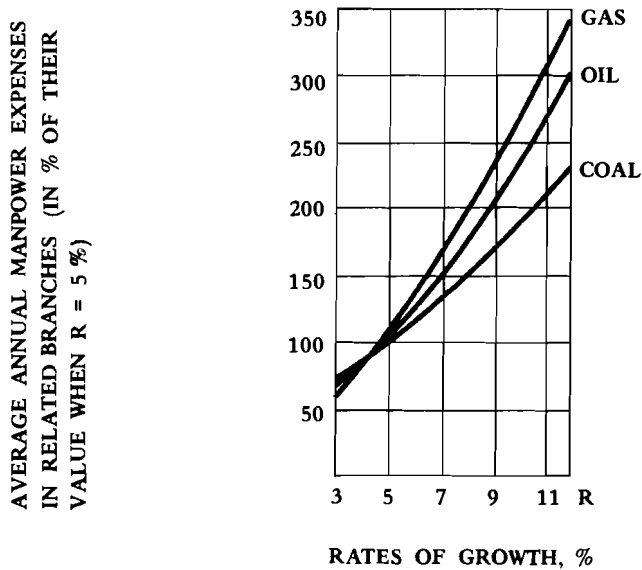


Figure 2. Dependence of indirect manpower expenses on the growth rates of fuel mining.

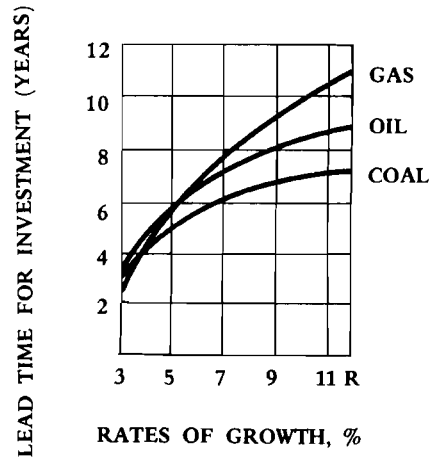


Figure 3. Required lead time for indirect investment.

Experimental calculations have shown that in the case of excessive forcing of the share of Siberian gas, oil, and coal in the fuel-power balance of the European part of the country, the indirect capital investment can amount to 40-55 percent of the direct investment (see Table 1).

Table 1. Indirect capital investment in the development of some Siberian fuel sources (%).

ENERGY-RELATED INDUSTRIES	OIL	GAS	COAL
Electric Power Systems	3	2-3	9-10
Fuel Industry	12	8	14-13
Ferrous Metallurgy	28	38	18-19
Non-ferrous Metallurgy	4	2-3	4- 5
Construction Material Industry	20	22	16-15
Machine Building	12	10	17-18
Other Branches	21	17	22-20
Total	100	100	100
The same as a percent of direct investment	54	47	43-45

ACCOUNTING FOR INDIRECT EXPENSES

As a rule the criterion of minimum discounted costs for supplying the total energy demand is used for the optimization of the energy economy. Expenses for developing related industries are then reflected in the price of energy. This is effective only for short-term planning, or on condition that the prices are adjusted in the course of iterative coordination of plans of individual industries and the national economy as a whole. Otherwise, the indirect expenses (especially indirect investments) must be taken into account explicitly.

The simplest way to do such accounting is by the use of additional criteria for comparing the variants, differing only slightly from the main criterion.

For example, let us consider the two variants of energy supply shown in Table 2. In variant 2 an additional amount of about $100 \times 10^9 \text{ m}^3$ of Siberian gas is transferred to the European part

Table 2. Energy supply variants (variant 2 expressed as a percentage of variant 1.

	Variants	
	1	2
Oil	100	100
Gas-total	100	110
incl. Siberian gas	100	122
Coal-total	100	79
incl. Siberian	a) Kuznets coal b) Kansk-Achinsk coal	88
		58
Nuclear power plants	100	100
Transmission line from Siberia	100	-
<u>Sum of discounted cost</u>		
(objective function)	100	99.7

of the country. This makes it possible to reduce the output and transportation of Siberian coal and also eliminates the need for building the high-voltage transmission line from Siberia to the center of the country. Both variants are practically equal from

the point of view of the objective function or discounted cost but differ in their influence on related industries. The second variant requires an increase in the productive capacities of related industries (specifically ferrous metallurgy, construction materials, and machine building) and hence an increase in indirect investments and manpower expenses (Table 3).

Table 3. Additional indirect investment and manpower required for variant 2 in Table 2.

I. Capital Investment (Million Rubles)	2975
Ferrous Industry	1900
Non-Ferrous Industry	-100
Construction Material Industry	150
Building Industry	750
Machine Building	50
Other Branches	235
II. Manpower (thousand of man/year)	40
For Operation	28
For Construction	12

CONCLUSIONS

Large-scale, capital-intensive programs, such as the program for the assimilation of Siberian energy resources, strongly influence the development of many branches of the national economy. Capital investment and other expenditures for developing the energy-related branches can be roughly evaluated with the help of a special interindustrial dynamic model, built up in the Siberian Power Institute. A new version of this model is being designed at IIASA for evaluation and comparison of long-range energy strategies.

In conditional long-range forecasting, where prices and constraints have maximal uncertainty, the minimum sum of direct and indirect capital investment and other limited resources may be considered an additional criterion for comparing variants.

Comparing strategies in terms of this additional criterion is not enough in cases of particularly significant changes in the structure of the energy balance or where there is a rapid transition to new capital-intensive energy technologies. In the process of optimization, the direct and indirect production relationships of energy systems with other branches must be taken into account by means of correcting the objective function and constraints on the use of limited resources. Such an approach for a perspective of more than 20 years is being developed at IIASA.

Physical and Mathematical Simulation for Solving
Problems of Power System Functioning

Yu.M. Gorsky and Yu.S. Konovalov

Large electrical power systems occupy an important place in large-scale energy systems [1].

Two basic organizing processes, namely, development and functioning, are characteristic of electrical power systems as they are of large progressive systems. Though these processes proceed side by side, there are certain differences between them.

If a large-scale system is described by a set of elements N and a number of connections M , then its functioning is the solution to a certain number of problems represented by a tree of problems for a given N_g and M_g in the system, and the attainment of certain objectives represented by a tree of objectives. Adaptation of the system, i.e., changes in its properties, composition, and structure, proceeds at a comparatively rapid rate, within the limits of N_g and M_g . Development of the system takes place largely through an increase in N and M , whereas adaptation, from the viewpoint of the development of the problem, is a slow process.

Another important distinction between functioning and development lies in the control objectives. The functioning objectives can be broadly formulated and represented in mathematical language, while the development objectives in most cases prove to be "incompletely defined" or "subjective" [2]. Because of this, there is great scope for physical and mathematical simulation of electric power systems in normal operation and in emergency situations.

In this paper we briefly outline the research conducted at the USSR Siberian Power Institute on such simulation methods applicable to the study and control of transient processes in electric power systems.

SYSTEM INFORMATION METHODS OF ANALYSIS

The functioning of an electric power system is described by a tree of problems and control objectives attained through control algorithms represented as a tree of control nodes (Figure 1).

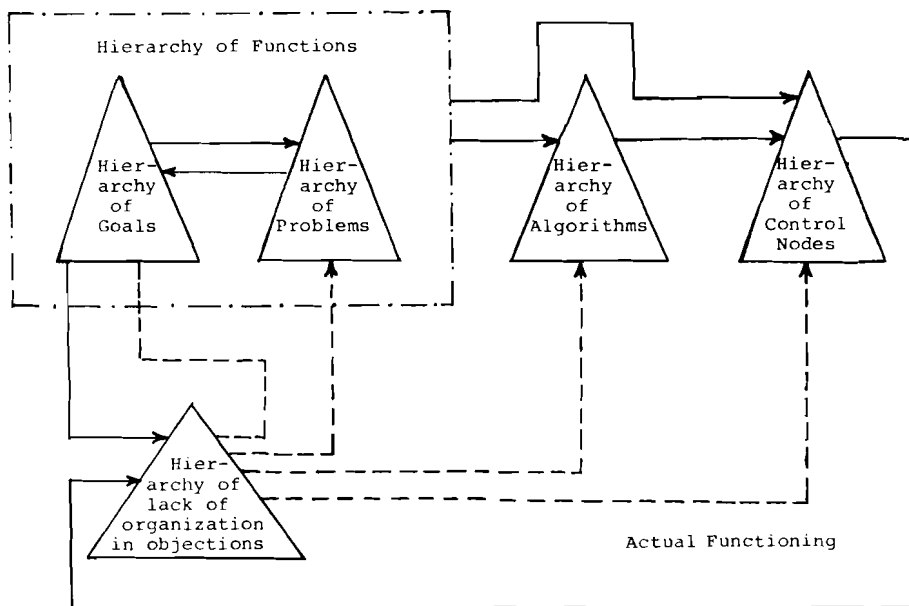


Figure 1.

For a complex hierarchical system the sets of objectives and problems may be represented as graphs with a predominantly hierarchical ordering rather than as trees because the subgoals may interact and the goal may effect the subgoals.

The control nodes for functioning follow from the design of the system and may be either man-computer control systems or automatic control complexes. The principles underlying the design of the main elements and units of current control for an integrated national power system are examined in [3].

Perception, recognition, prediction, decision making, and execution are the basis of any control. All these processes except the last are informative. An organizational version of the information theory of control and simulation is being designed for a quantitative analysis of these processes [2,4,5,6]. It can be described as follows:

- The functioning of a system is studied in relation to its control objectives which might be vague in a general case;
- Information flows are estimated both quantitatively and qualitatively in terms of their effect on the attainment of objectives;

- As regards the data conversion quality, the algorithms are estimated in terms of data transfer functions irrespective of whether a man or machine is converting the data;
- Man or machine limitations for data conversion, due to a lack of adequate memory or speed, are taken into account in the efficiency factor.

In this approach the degree of nonattainment of the i th objective may be represented as the index of lack of goal-oriented organization

$$\bar{O}_i = \sum_{j=1}^n p_j W_t \psi(\Pi_{\bar{Y}_{ij}}),$$

$$\Pi_{\bar{Y}_{ij}} = f(Y_{ij}, \omega_{ij}), \quad Y_{ij} = \phi(q_{ij}, \xi_{ij})$$

where n is the number of situations; p_j is the probability of the j th situation; \bar{Y}_j is the disorder of functioning in the j th situation as regards the i th objective; ψ is a function representing the effect of the parameter of lack of organization; ω_j is the weight of the j th situation in relation to other situations with the same function $\bar{\psi}$; q_j is the difference between the system state vector and the objective vector; ξ_j is the magnitude of the vector of distance from the internal boundary of the objective domain to the objective vector; and W_t is a time relation describing, for instance, aftereffects, lag, and accumulation.

For a wide class of systems, in a limited time interval in which $W_t = 1$, the following relation of the lack of organization of the d th objective and the lack of organization of its related subgoals [5] can be established:

$$\begin{aligned} \bar{O}_{(c)d}^{(m+1)} = & 1 - z_d \left(1 - \gamma_1 \bar{O}_{(ex)}^{(m)} \right) \left(1 - \gamma_2 \bar{O}_{(ex)2}^{(m)} \right) \dots \left(1 - \gamma_k \bar{O}_{(ex)k}^{(m)} \right) \\ & \times \left(1 - \gamma_{k+1} \bar{O}_{(ex)k+1}^{(m)} \rho_{k+1} - \gamma_{k+2} \bar{O}_{(ex)k+2}^{(m)} \rho_{k+2} \right. \\ & \left. - \dots - \gamma_n \bar{O}_{(ex)n}^{(m)} \rho_n \right), \quad z_d = a_1 + a_2 z_{efdB}, \end{aligned}$$

$$Z_{\text{ef}\alpha\beta} = L_{\text{eq}} \eta_{\text{eq}} \eta_{y\beta} I_{*\beta}^{\alpha}, \quad \gamma_i = 1 + \gamma_{id} + \sum_{\substack{\ell=1 \\ \ell \neq i}}^n \gamma_{i\ell},$$

where $\bar{O}_{(\text{ex})i}^{(m)}$ is the lack of organization as regards the i th objective of the m th level expressed in terms of the index of the d th objective; Z_d is the organization factor of the d th objective; ρ_i is the coefficient of relative influence of $\bar{O}_{(\text{ex})i}^{(m)}$ on $\bar{O}_{(\text{ex})d}^{(m+1)}$; γ_i is the coefficient of inverse effect of the lack of organization of d th objective on the lack of organization in the i th objective and the effect of other subgoals of the m th level on it; $Z_{\text{efd}\beta}$ is the coefficient of the effectiveness of the node β responsible for attainment of the d th objective; L_{eq} are equivalent converting properties of the algorithms used in the node β ; η_{eq} is the equivalent information efficiency of the node β showing the extent to which its algorithm is used; $\eta_{y\beta}$ is the reliability index for decisions made in the executive units of the β th control node; $I_{*\beta}^{\alpha}$ is the amount of value-weighted information fed to the input of the β th control node; γ_{id} is the coefficient of inverse effect of the d th objective on the i th subgoal; and $\gamma_{i\ell}$ is the coefficient of interaction of the i th subgoals.

System information methods have found application only recently in the analysis of the functioning of electrical power systems. The research in the Irkutsk hydropower station is one of the first applications of system information methods for analyzing power system functioning. For normal operation, a tree of about 150 objectives was constructed with four hierarchy levels; the main information flows were identified and quantitatively estimated. The levels were selected to suit the existing hierarchy of control nodes in power stations.

Further extensions of system information methods include principles for the conversion of complex objective graphs into pure trees, for the projection of subgoals at the level of a goal and for inverse projection, namely, projecting a goal at the level of a subgoal, etc.

System information methods may prove to be of use not only for analyzing the functioning of large systems of different types, but also for analyzing a number of problems in the development of large-scale systems.

STUDY OF POWER SYSTEMS OPERATION IN A HYBRID COMPUTING SYSTEM

Hybrid (i.e., a combination of digital and analog computation) is a promising trend in computing technology. When combined with a physical model it seems especially promising for

studying the transient processes in electrical power systems [7]. We have already gained some experience in the development of hybrid systems and their applications in research.

Brief Description of the Hybrid-Computer-Physical Model System

The system consists of a digital computer, analog computers, an electrodynamic model, and various interfaces [8]. The electrodynamic model contains seven simulation synchronous generators. To control their rate and excitation, simulation controllers, or special purpose analog computers, are used. The compensators are simulated by eight 3 kVA power blocks. Busbars of "infinite" capacity are simulated by a unit consisting of a 875 kVA synchronous generator rated for 3.15 kV, coupled with a 360 kW synchronous motor and a link between the model and the 6 kV mains through an induction voltage regulator.

The model can simulate 10,000 km long transmission lines carrying 220 to 700 kV. It can also simulate their frequency dependence up to the seventh harmonic simulation by selecting the sizes of phase coils and by using two RL circuits for the ground wire resistance. The simulated transmission lines have facilities for longitudinal and transverse compensation.

Simulated 1.6 and 10 kVA single-phase transformers, and 5 and 30 kVA three-phase transformers have a wide control range both on the step-up and step-down sides. The 1.6 kVA transformer can simulate all basic parameters of large power transformers including idling characteristics [9].

To simulate the load nodes the model includes seven cage motors, three rotary field motors, and five rectifiers and variable resistors.

The model is quickly switched on and off by high-voltage contactors. It is controlled and the process parameters are recorded in a panel carrying all the test circuits and remote controls. The digital-analog part includes the digital control computer and the analog computer. The computing part can be connected to actual hardware such as regulators and actuators [10].

The data collection and information display system consists of: electrical sensors which convert model parameters into normalized electrical signals; commutation fields for selecting the desired parameters intended for display and recording; switchboards for monitoring signals from sensors for observation and recording; read-outs of conditions in elements (oscillographs, instrumentation); a unit for recording the transient processes (multi-output recording oscilloscope); and a unit for complex data processing and centralized recording.

All data collection, display, and recording are controlled from the panel by means of a control computer. The data collection system is closely tied up with the model mode control system.

The operating modes of all elements are controlled from the panel. For smooth take over of control by the operator from the computer or by the computer from the operator and for increasing the processing rates, the generators and motor are controlled by stabilization units.

Analog-to-digital and digital-to-analog converters were given much attention in developing the system [8].

Automation of Experiments

The system can operate in any of the three modes: electrodynamic simulation; mathematical simulation in the analog and digital parts; or physical simulation simultaneously in analog and in digital parts.

As regards automation the experiments can be divided into a number of mutually interrelated stages: (I) preparation, (II) tests, (III) experiment proper, and (IV) processing of results.

Special purpose systems and sufficiently multipurpose software are needed for the successful realization of these four stages.

At stages I and II: (a) the actual electric power system is represented by an equivalent circuit suitable for simulation on the available hardware; and (b) tests are performed: to check whether the characteristics of generators, transformers, and lines correspond to those of the elements in the equivalent circuit, etc. and to check the model as a whole in order to verify whether its behavior characteristics correspond to those of the equivalent circuit (voltage levels in the nodes, excess currents in the lines, etc.).

The multipurpose computer programs used at the preparatory stage include a program to study the feasibility of making an equivalent circuit; a program to compute equivalent parameters of the "contracted" circuit and to select the simulating hardware; and a program to compute the test regimes of elements and the entire circuit.

The tests are automated as far as possible by using the following control computer programs for:

- (a) Setting the physical model capacity overflows so as to obtain the desired condition before the experiment;
- (b) Three versions of the sensor interrogation program to collect quickly the data on the state of the electrodynamic model and to obtain a preliminary estimate of the condition there;
- (c) Setting the variable load so as to control the automatic load unit.

Items (b) and (c) above are programs of the control computer and include a number of subprograms, e.g., the sensor interrogation program. It would be very difficult or even impossible for the system to operate without special purpose units generating and implementing control actions on system elements, e.g., mode stabilization and attainment units.

Many electrodynamic simulation experiments have to be repeated with the same mode of the system under study. To attain the desired mode, continuous action on rate and excitation regulators of simulated generators is needed. When the circuit is complicated (i.e., there are several machines) this becomes a labor consuming and ineffective operation, because much time is needed for a synchronous circuit to attain a mode (15 to 30 minutes for a six-machine circuit) and, more important, the synchronous dynamic stability may be disturbed because the static limit may be violated if the mode is close to those limits.

An automatic system is available for controlling the power of an asynchronous simulated load according to a given schedule [11]. The methods and programs for the experiment itself are described in detail in [12].

DIGITAL AND ADAPTIVE METHODS OF DIRECT CONTROL

Digital methods of data conversion and adaptation principles have been shown to play an important role both at lower and upper levels of the hierarchical controlling electric power systems, i.e., at levels of direct process control [3].

Several generations of digital and hybrid regulators have been developed for the excitation of synchronous generators [12]. One such regulator has been successfully tested in the Bratsk hydropower station [13]. These tests were preceded by studies of the principles underlying digital control by a digital-analog-physical combination. The latest specimens of digital excitation regulators are hybrids built on an LSI-base with a structure rearrangeable by instructions from a higher echelon of control, and a self-monitoring system. They can generalize (condense) the input data.

Adaptation algorithms and their mock-ups [14] permit the automatic optimization of the dynamic properties of systems during operation--large disturbances are suppressed. Adaptation criteria are integral estimates of the weighted difference of errors in amplitude-frequency or amplitude-phase frequency dynamic responses [14]

$$S_1 = \sum_{i=1}^n a_i(t) \int_{\omega_{i-1}}^{\omega_i} (A(\omega) - A_{\text{ref}}(\omega)) d\omega ,$$

$$S_2 = \sum_i^n a_i(t) \int_{\omega_{i-1}}^{\omega_i} (W(j\omega) - W_{ref}(j\omega)) d\omega ,$$

where $a_i(t)$ is a sign-variable weight (significance) of the i th portion of the frequency response, thereby representing the significance for adaptation of the varying mismatch in different parts of the frequency response; $A(\omega)$, $W(j\omega)$ are dynamic amplitude-frequency and amplitude-phase-frequency responses, respectively; and $A_{ref}(\omega)$, $W_{ref}(j\omega)$ are the set-points of amplitude-frequency and amplitude-phase-frequency responses respectively.

It should be emphasized that here we mean those dynamic frequency responses that result from continuous variations in frequency, or are obtained within 5 to 20 seconds.

The adaptation algorithms were studied with the use of the digital-analog-physical combination in automated experiments.

DIAGNOSIS AND ESTIMATION OF MODES IN ELECTRIC POWER SYSTEMS

With the increasing complexity of electric power systems and the increasing requirements for their reliability and controllability, the need arises for supplementary information both for the prevention of emergencies and for the determination of the state from inadequate data.

Diagnosis

Existing methods of fast diagnosis used for the identification of modes in electric power systems can be divided into three main techniques as regards the parameters measured: measurement of averaged mode parameters, such as voltage, current, power, vector shift angle, and frequency; fast measurement of frequency responses which are generalized indices of dynamic properties for an electric power system; and measurement of the shape of periodic signals.

The first technique is already in use in electric power systems. The second is promising but still not in use because it requires automatic measurements in 5 to 30 seconds of amplitude-frequency responses of system parts during normal operation. These are actually dynamic rather than the conventional frequency responses; they are determined when disturbances are fed with a frequency variation according to a specified law in a specified frequency range [14]. The feasibility of obtaining dynamic frequency responses in actual conditions was verified at the Bratsk hydropower station [15]. The hardware developed in a joint project with the Czechoslovak Academy of Sciences [16] may serve as the core for supervising the dynamic properties in electric power systems.

The diagnostic technique, where the criterion is the shape of the periodic signal, is also very promising but has not been widely applied in electric power systems although extensive work has been carried out on hardware for measuring the indices of shapes and on the introduction of such signals into digital computers. For an example of such work [17].

Estimation

Incomplete observability of an electric power system, relatively low accuracy of remote measurements in actual electric power systems, and noise in communication channels call for new ways of obtaining additional data. These can be obtained through estimation or from statistical computer processing of present day measurements [18]. Multipurpose computers and digital-analog-physical facilities can be conveniently used for this, since they can simulate the estimation of states with due regard for data sensors and the effect of noise. The accuracy of the measurement system should be checked, the vector of measurements should be determined with subsequent processing of the resulting measurements, the effect of the sequence in which the units are interrogated on the resulting estimates should be determined, etc.

STUDY OF EMERGENCY PREVENTION SYSTEMS

The carrying capacity of existing transmission lines is sometimes not adequate to meet planned or maximal emergency capacity created by the power feed from new large-capacity stations. The stability of the parallel operation of power stations can be improved by emergency dismemberment of the system; shut-down of some generators in hydropower stations; boosted excitation; shut-down of shunting reactors at switching points, etc.

The emergency prevention facilities should be capable of automatic emergency control of active capacity in order to maintain stability; automatic limitation of frequency increase; automatic cutout of asynchronous operation; and protection against voltage increase.

To determine the data on the circuit and the mode in the grid, and to use these data to activate the main controls for expected emergencies, requires the development of digital computing logic devices. Before an emergency arises these devices must compute the necessary actions for all start up units and prepare the appropriate output circuits. The data input and output should be digital in order to create remote links with computers at a higher control level. These questions are studied in the digital-analog-physical combination with special reference to the Eastern part of the Siberian Power System, and the commissioning of the Ust-Ilimsk hydropower station where both the generating equipment and the transmission lines are to be introduced in stages. At the first stage, three generators will supply the busbars of the Bratsk station through two 220 kV transmission lines and, at the

second, through two 500 kV circuits. Thus it was necessary (a) to determine the static limits of transmission through 220 kV lines with strong and proportional action controllers in the generators at the Ust-Ilimsk station--one- and two-circuit options were studied; and (b) to determine dynamic limits of the same lines with the same controllers.

An experimental circuit was set up in the electrodynamic model to simulate the Bratsk and the Ust-Ilimsk stations. The former comprised three simulated generators and the latter one. The transmission lines were found capable of transmitting the power of three generators at the Ust-Ilimsk station to the vicinity of Bratsk city, and limits were determined for the power to be transmitted and for dynamic stability. The generators were found to resynchronize rapidly at a given power transmission level for a two-phase short circuit.

Approaches to the Design of a Supervisor's Advisor in Emergency Situations

In electric power systems, developing regimes can arise when protection and emergency prevention devices fail or malfunction and the interference of the supervisor is needed. It is not possible for the supervisors to detect such situations and select programs for their elimination because data and time are short. A computer advisor may prove useful and should perform four functions: determine the system state on the graph of possible emergencies; determine the preferred policies for the specified objectives; forecast fluctuations in the system between two qualitatively different states; and optimize the control action. It is also desirable that the supervisor be able to transfer his experience and intuition in recognizing and selecting policies. For this purpose recognition and control selection methods were developed in logic circuits, using reversal logic models [19]. The developing processes with transitions to qualitatively different states can be described as a Moore's probabilistic finite automation without loops in the space of generalized cause $x(x_1, x_2, \dots, x_n)$, generalized criteria $y(y_1, y_2, \dots, y_k)$ and states $A(a_1, a_2, \dots, a_m)$, and its functioning was defined by transition operators f and output operators ϕ .

The studies confirmed the utility of these programs and two-level models where one level simulates qualitative malfunctions and the other functional breakdowns. The advisor needs to be compatible with a hybrid computer.

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Energy Accounting

F. Niehaus

The basis for determining the optimal energy supply strategy for the rapid industrialization of a large region like Siberia is the exact calculation of the energy demand for the building and operation of the facilities. In a positive feedback loop the rapid growth of energy systems creates an energy demand.

Calculating the demand is an important task of the IIASA approach to energy systems. As shown in Table 1, IIASA concentrates on three approaches to calculating the demand for energy.

Table 1. IIASA's approach to calculating demands.

Approach	Time Scope (years)
Econometric Calculations	5 - 15
Energy Analysis	10 - 30
Endogenization of Growth Models	20 - 50

The time period for the possible application of the various methods overlaps. The reliability of econometric calculations is limited to a time span of about 5-15 years as they use constant or extrapolated econometric relationships. The implementation of new energy systems or the development of new large-scale industries on the regional or national level will alter these parameters considerably. On a medium scale of 10-30 years, improved data can be obtained by energy analysis. Long-term calculations of the demand models are being constructed, which will allow one to explain endogenously the parameters that influence the rates of energy consumption.

The term "energy analysis" describes methods for calculating the total energy needed to produce a unit of a consumption good; that is, in the case of power plants, to calculate the total energy balance or "budget" of energy facilities [1,2].

Figure 1 describes some basic problems and implications using a simple example. Generally, two approaches are being

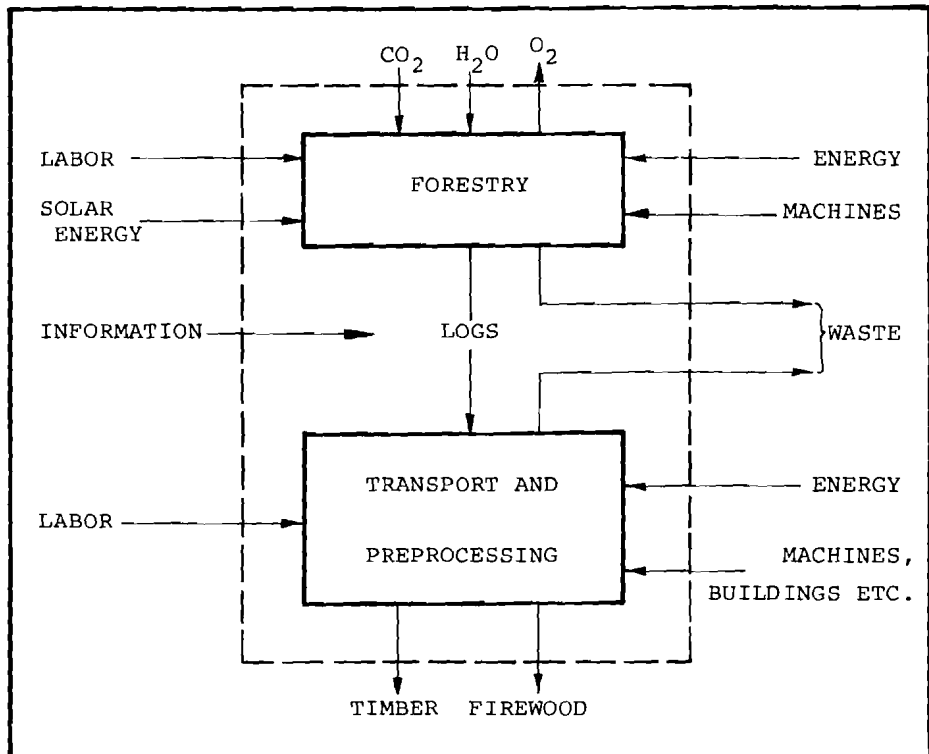


Figure 1. Definition of systems and energy input.

investigated by IIASA [3,4]. Let us deal with the branch of industry described in Figure 1. This industry uses natural supplies, industrial goods, manpower, energy and information to produce timber, firewood and waste. To calculate the energy requirements for producing, say, one cubic meter of timber, the first step is to define adequate subsystems for which balances of the energy flows have to be compiled.

One possibility is to consider a variety of well defined production steps. By means of a process chain analysis, the total amount of energy can be calculated by tracing back each step of production. This method is outlined by the solid lines in Figure 1. On the other hand, one can try to define a system-- the boundary of which crosscuts all important inputs and outputs.

This is indicated by the dashed line. Both procedures raise a couple of basic problems. Energy of different thermodynamic values has to be compared (e.g., heat and electricity), inputs of labor, solar energy and information have to be defined, etc. The most crucial problem is that of distributing the input energy to the goods produced in the same process, in this example, timber, firewood and waste. Physical criteria for this distribution, such as weight, and heating value, serve badly because they neglect the importance of a good to the economy. Therefore, the approach described below calculates the value of the produced goods as a criterion for the distribution of the energy used. This method automatically takes account of the energy which would be assigned to the waste according to physical criteria.

If the value of the produced goods is accepted as a criterion for the energy distribution, then the input/output tables of economies can be used. These tables give the flow of goods in an economy in terms of money. The principal shape of an input/output matrix \underline{A} is given in Figure 2. The coefficient a_{ij} gives the percentage of the total output of the industrial sector

SECTOR	1	j	Y	Σ
1		↑ TO				X_1
⋮	← FROM					
i			A_{ij}		Y_i	X_i
⋮						
$X_i = \sum_{j=1}^n A_{ij} \cdot X_j + Y_i$						

Figure 2. Input/output coefficient matrix.

j, which was bought from sector i in the form of raw materials, equipment, maintenance, etc., for the immediate production. For small changes in time, equilibrium of money flows may be assumed. Therefore, these relationships can be written in the form of the equation given at the bottom of Figure 2, if X_i is the total production of sector i and Y_i is the production of consumption goods. In the form of matrices this can be written as:

$$\underline{X} = \underline{A} \times \underline{X} + \underline{Y} \quad (1)$$

The solution of equation (1) leads to the inverse Leontief matrix. That is

$$\underline{X} = \underline{(I - A)}^{-1} \times \underline{Y} \quad (2)$$

According to equation (3) this can be developed into a sum of power functions of \underline{A} . That is

$$\underline{(I - A)}^{-1} = \underline{I} + \underline{A} + \underline{A}^2 + \underline{A}^3 + \dots \quad (3)$$

A simple explanation of this relationship is given by the following calculation. The production of a vector of consumption goods \underline{Y} directly requires the production of \underline{Z}_1 . That is

$$\underline{Z}_1 = \underline{A} \times \underline{Y} \quad (4)$$

The production of the product vector \underline{Z}_1 directly requires the production of \underline{Z}_2 . That is

$$\underline{Z}_2 = \underline{A} \times \underline{Z}_1 = \underline{A}^2 \times \underline{Y} \quad (5)$$

The sum of all direct and indirect requirements is then given by

$$\sum_{n=1}^{\infty} \underline{Z}_n = (\underline{A} + \underline{A}^2 + \underline{A}^3 \dots) \times \underline{Y} \quad (6)$$

Therefore, the order of the power functions of \underline{A} give the order of indirect requirements.

These calculations can be extended to energy flows by introducing a matrix of specific energy consumption coefficients \underline{R} , the elements of which are defined by

$$R_{ij} = \frac{E_{ij}}{X_j} \quad (7)$$

where E_{ij} is the energy flow of type i (e.g., coal, oil, electricity) to industrial sector j . The dimension of \underline{R} is given by units of energy divided by units of money. The product

$$\underline{V} = \underline{R} (\underline{I} - \underline{A})^{-1} \quad (8)$$

gives information on the total direct and indirect energy requirements for producing industrial goods of the end consumption.

These estimates do not take account of investments which can be included by the following calculation. The input/output tables give investments as part of the end production. Thus, the amount of energy to produce the investments can be calculated. An adequate percentage can then be added to the total requirements.

In the Federal Republic of Germany (FRG) for example, the above method for energy accountance has been applied, and some results are given in Figure 3. In principle, two groups of products can be distinguished, the first covering the range of 30-40 kg coal equivalent per 100 DM (1\$ $\hat{=}$ 2.6 DM), and the other group covering the range of 60-80 kg coal equivalent per 100 DM, which indicates roughly a factor of 2 between these groups. The energy intensive sectors 6, 7, and 9 to 11 produce raw materials and goods whereas sectors 8 and 12 to 16 produce ready-made goods. The highest specific energy demand is given by the transportation sector (17), and the lowest by the sector of general services (18). This strongly indicates that with a growing degree of sophistication in the production of goods, energy is substituted by information.

These results depend on the definition of energy inputs and outputs by imports and exports of goods. The results displayed in Figure 3 were obtained with the following assumptions and mathematical procedure.

The first step calculated the physical energy content of the energetic imports to the FRG. According to these inputs the specific total energy requirements for the production of goods are calculated. These parameters are used to calculate the energy

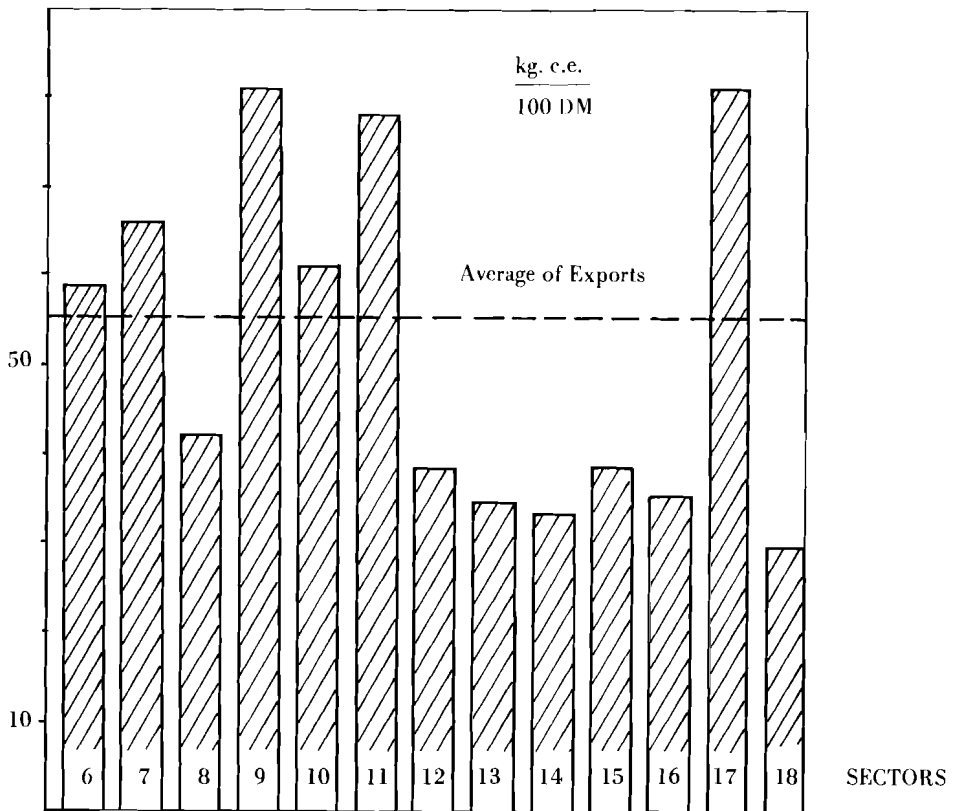


Figure 3. Energy demand for selected industrial goods, FRG, 1970.

requirements for the production of exports, and the exports make it possible to pay for the imports. For special trade contracts, imports and exports are not directly related, average values of the specific total energy consumption for the production of export goods were calculated.

In a second step, these values were taken to estimate the energy requirements for the imports of nonenergetic goods, which then result in changed total requirements. Therefore, these calculations lead to an iterative procedure which is rapidly converging.

Because of the use of the input/output table of an economy, the obtained results are closely linked to the economy of that region. Different results will be calculated for different regions, thereby taking account of the real relationships of the economy, but they may provide a useful tool for calculating the time dependent energy balance for rapid growing industrial regions like Siberia.

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The Role of the Bratsk and the Ust-Ilimsk Hydropower
Stations in the Joint Siberian Power System

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The construction of the Bratsk hydropower station (HPS) and the high voltage transmission lines that link it with the areas of Irkutsk, Krasnoyarsk, the Kuznetsk Coal Basin, and Novosibirsk, have determined the zone of influence of the Angara HPSs in the development of the productive forces of Siberia.

Because of the guaranteed output of the Bratsk HPS and the regulating potentials of the Baikal Lake and the Bratsk reservoir, the Bratsk HPS has become the main power station within the energy supply system of Central Siberia [1].

In choosing the parameters for the Bratsk HPS, account was taken of the conditions of its interaction with other power stations of the Angara-Yenisei cascade and of the compensating effect of the Bratsk HPS on the poorly regulated capacities of the Yenisei HPSs--Krasnoyarsk, Sayano-Shushenskaya, and Mid-Yenisei [3].

In 1960, a joint power system (JPS) for Siberia was established in order to create a reliable power base for the country's eastern regions. This is in line with the industrialization policy set out by the Communist Party of the Soviet Union (CPSU). Currently, the Siberian JPS covers an area of about 4 million km² with a population of 16 million.

The electricity network is about 3000 km latitudinally and up to 1000 km meridionally.

As of 1974, the Siberian JPS comprises eight regional power systems, with a total installed capacity of the electric power stations amounting to 26 million kW, and an annual output of 13.4×10^9 kWh.

Hydropower plants account for 40 percent of the total electricity capacity of the Siberian JPS. An increase in the capacity of the existing Ust-Ilimsk HPS is expected, and the Sayano-Shushenskaya HPS is under construction.

The Angara-Yenisei cascade produces 98 percent of the JPS's total power output, of which no less than 70 percent is accounted for by the Angara HPS stations--Irkutsk, Bratsk, and Ust-Ilimsk.

All HPSs of the Angara-Yenisei cascade are complex installations designed to meet the requirements of the power industry, water transport, fishery, water supply to towns, and industrial and water-economy projects.

The Angara hydropower plants provide high quality, reliable power to the Siberian regions, and perform the following functions within the JPS:

- Balance the greater part of the daily and weekly load irregularities;
- Ensure the rotating reserve for frequency control and the system's emergency reserve;
- Serve as the long-term power regulator responding to both the irregularities in the development of the power generation capacities of the Siberian JPS and the fluctuations in the output of the Krasnoyarsk HPS.

The power supply pattern and operating conditions of the HPSs follow the general guidelines for the development of the Siberian economy, where industry remains the major energy consumer (85 percent). Electric railways also consume power (10 percent), especially along the 3000 km section of the Trans-siberian Railway.

The Directives of the 24th Congress of the CPSU on the Ninth Five-Year Plan of Development for the USSR outlined the formation of new and the further development of existing territorial-industrial complexes in the eastern part of the country, namely, the Bratsk, Ilmsk, Sayany, and Boguchany complexes, which comprise major ferrous and nonferrous metallurgical, machine-building, ore-mining, and wood-processing plants.

An aluminium plant and a major timber industrial complex have been commissioned in Bratsk; a large-scale ore-dressing integrated plant is now operational based on the Korshunovo iron-ore deposit.

Ferrous and nonferrous metallurgical facilities as well as industrial chemistral plants are being developed in the Irkutsk-Cheremkhovo Region using the cheap electric power supplied by the Angara hydropower plants. These plants also influence the development of the Krasnoyarsk and Kuznetsk basin industrial complexes which account for nearly 25 percent of the national coal output and have ferrous and nonferrous metallurgy, chemistry, machine-building, and other industries.

The development of energy-intensive industries with continuous production cycles has resulted in a highly crowded load schedule for the Siberian JPS. The load coefficient for this schedule is 0.92 to 0.93, and the nonuniformity coefficient is

0.82 to 0.85. The seasonal fluctuations in the electricity consumption schedule are less pronounced than those in the European part of the country; in the former the annual peak load time is 6600 to 6700 hours.

Recently, the growing demand on the part of the Siberian JPS for power and energy has been met by commissioning large-scale hydropower plants.

During the period of the initial filling of the Bratsk HPS reservoir (1961-1967), its capacity was expanded to allow up to 63 percent of the annual increase in power consumption to be covered for the JPS as a whole. This share remained unchanged until 1970, owing to the commissioning of new capacities at the Krasnoyarsk HPS, with the Bratsk HPS operating at designed capacity. In the near future, the increase in power demand of the Siberian JPS will be largely covered by commissioning new capacities at the Ust-Ilimsk and the Sayano-Shushenskaya HPSs.

After the first power units of the Bratsk HPS became operational and the high voltage transmission lines connecting it with the western systems were built, it was possible to provide the Siberian JPS with a reserve capacity for the unlimited supply of electricity to consumers and the necessary repair and maintenance operations at the power stations. A steady increase in the output of the Bratsk HPS and the development of the electricity network made it possible to tackle the problems of optimum operation of the entire Siberian JPS.

The role of the Angara HPSs in offsetting the fluctuations in the load schedule of the JPS ensured the operation of the thermal electric power stations at the rated capacities of their equipment. Under these conditions, the best economic indices for the operation of the thermal electric stations and the Siberian JPS as a whole were achieved.

During the period 1961-1967, the cost of electricity in the Siberian JPS declined from 0.58 kopek/kWh in 1961 to 0.50 kopek/kWh in 1967. The high energy indices of the Bratsk HPS with its 18 units in operation satisfied all the requirements for the system's reliability and made it possible to optimize the operating conditions inside the HPS. The regulating and technological measures recently implemented at the Bratsk HPS are expected to result in an estimated 500 million kWh of additional power output at the given runoff.

The capacities of the newly commissioned HPSs of the Angara-Yenisei cascade are, of course, greater than the initial amount of power consumed, which explains the excess of installed capacity of HPSs in the first years of their operation within the JPS. This excess is subsequently eliminated [2].

The nonuniform growth of generating capacities is typical of the Siberian JPS at the current development stage and is due

both to the continuing commissioning of new large-scale HPSSs of the Angara-Yenisei cascade and to the HPSSs' exceptionally high share in the total power balance of the system. Under these conditions, the enormous possibilities of the Angara HPS reservoirs for runoff redistribution over a long period can ensure the rational development and efficient operation of the power system.

The operating conditions of the system in 1970-1974, prior to the commissioning of the Ust-Ilimsk HPS, illustrate this fact (Table 1).

Table 1.

	1970	1971	1972	1973	1974
Total output of electricity of HPS of Angara-Yenisei cascade (in 1×10^9 kWh)	42.2	44.3	46.1	48.9	48.5
Output of electricity of the Bratsk HPS (in 1×10^9 kWh)	20.3	22.8	23.3	23.0	28.0
Bratsk HPS output (in percent)	48	51	50	47	58

The Bratsk HPS plays a major role in covering the winter peak load of the Siberian JPS (Table 2).

Table 2.

	1970	1971	1972	1973	1974
Contribution of all HPSSs of the Siberian JPS to covering annual peak loads (in thousand kW)	5990	6470	6590	7160	7700
Contribution of the Bratsk HPS (in thousand kW)	2760	3660	3420	3040	4090
Bratsk HPS contribution (in percent)	46	57	52	42	53

The data illustrate the role of the Bratsk HPS in regulating the output and covering the consumption peak loads of the HPSs of the Siberian JPS.

After the first units of the Ust-Ilimsk HPS became operational in 1974, the contribution of the Angara cascade to the operations of the Siberian JPS increased substantially. The characteristic feature of the annual operating schedule of the HPSs of the Angara-Yenisei cascade in the period under consideration is a relatively high output in summer to meet the requirements of navigation. Such a schedule necessitates unloading the thermal power stations of the JPS, even those with highly efficient equipment. In winter, owing to a shortage of water power resources, the thermal stations need to be loaded to full capacity, which results in poor annual efficiency indices. In the event of an unusually greater runoff in summer and autumn in the Yenisei River basin, the excess runoff at the Krasnoyarsk HPS will affect the operating conditions of the thermal stations, since it is not possible to offset these excess water resources by decreasing the output of the Bratsk HPS.

After the Ust-Ilimsk HPS was commissioned, the use of its reservoir made it possible in 1975 to greatly enhance the regulating potentials of the Angara cascade. A partial decrease in the Ust-Ilimsk storage capacity during the navigation season made the Angara navigable and also reduced the transit flow rate in the cascade by 2.8 km^3 ; this corresponds to a reduction of 700 million kWh in the Bratsk HPS output in summer and to an increase in its winter output.

The commissioning of the Ust-Ilimsk HPS, operating on a tributary controlled by upstream reservoirs, eased the water economy restriction on the participation of the Bratsk HPS in the daily and weekly regulation of the system's load schedule. All the excess water power resources of the Krasnoyarsk HPS obtained in the summer season can be stored at the Bratsk HPS by reducing its load in this season, thereby increasing the total output of the Angara-Yenisei cascade in winter.

In 1975, during the period from May-September, owing to the regulating capacity of the Ust-Ilimsk reservoir, the operation of the Bratsk HPS in the compensated regulation scheme with the Krasnoyarsk HPS ensured efficient operating conditions for the system's thermal power stations; it was possible to accumulate excess summer water resources in the Bratsk HPS reservoir estimated at 900 million kWh and to increase the Angara HPS total output in the winter of 1975-1976.

After reaching a capacity of up to 3.6×10^9 kW (15 units of the first stage), by the beginning of the winter period, the Ust-Ilimsk HPS will be able to ensure the operation of the Bratsk HPS in the maximum power output mode. The excessive consumption of the Bratsk HPS in winter, which is not covered by the

throughput capacity of the 15 units of the Ust-Ilimsk HPS, will be accumulated in the free part of its reservoir so that the normal design levels will be reached by the time the winter loads attain their maximum.

At the first stage of its capacity expansion (1975-1978), the Ust-Ilimsk HPS will thus have two cycles of drawing down and filling during one year, thereby making it possible to redistribute the energy output of the Bratsk HPS as a compensator of the Angara-Yenisei cascade's output with respect to seasonal conditions.

The projected expansion of the installed capacity of the Ust-Ilimsk HPS--up to 4.32×10^9 kW with 18 units in operation--will considerably upgrade the operational efficiency of the Angara cascade as a whole. By increasing the throughput capacity of the Ust-Ilimsk HPS, widening the capacity regulation range, optimally distributing the load among the units, and improving the cascade relationships with respect to the water flow, it is possible to increase the power yield of the HPS cascade, and allow the Angara HPS to offset the daily and weekly irregularities in the load schedule of the Siberian JPS.

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Angara-Yenisei Hydroelectric Power Station Cascade

A.Sh. Reznikovsky

Yenisei, the largest river in the Soviet Union, has a basin area of almost 2.5 million km², with an annual average runoff of 585 km³. The total length of the River basin is 90,000 km. The hypothetical hydropower potential of the river is nearly 600×10^9 kWh per year [1].

Vast mineral resources are concentrated in the Yenisei basin, especially in the basin of its right bank tributary, the Angara, which has its source in Lake Baikal. Among the resources discovered here are large coal deposits with a high carbon ratio, a favorable mode of occurrence and thick seams; iron ores; various aluminium raw materials; and other minerals such as rare metals, salt, mica, gold, diamonds, and graphite.

The area of the Yenisei mountain ridge, crossed by the Angara in her lower reaches, is particularly abundant in mineral resources. The Angara-Yenisei Region has rich forest resources.

Hydrographic exploration of individual rivers in the Yenisei basin was started late in the last century, but it was not until the early 1930s that a systematic study was started of the River's main stream and its tributary, the Angara. Suspended during World War II, this work was again continued in the postwar years on an even larger scale and culminated in 1953 in a scheme for exploiting the Angara River [2].

This scheme provided for the building of six hydropower stations (HPSs) on the Angara, with a total installed capacity of over 10 million kW and an average power output over many years equal to some 70×10^9 kWh per year [3]. Currently a somewhat greater figure of installed capacity is envisaged. One characteristic of this cascade is a high degree of regulation of the runoff, resulting from the Bratsk reservoir and the backwater of Lake Baikal. Capital investment for the main HPSs of the cascade was very low compared to similar outlays for thermal power plants.

The development of the Angara's power resources began with the establishment of the upper Irkutsk HPS, which has a capacity of 660 million; its first unit was commissioned in 1956. Later, the Bratsk HPS was constructed, with a capacity of 4×10^9 W; its first unit became operational in 1961.

The third station of the cascade, the Ust-Ilimsk HPS, is currently under construction; the first unit was operational in 1974, and the installed capacity is expected to be 3.6×10^9 W.

The total annual energy output of the above three HPSs on the Angara will be around 50×10^9 kWh [4].

The development of the Angara's power resources was carried out simultaneously with the creation of new major industrial centers in this sparsely populated area. Production specialization of these centers was determined by the nature of the neighboring power base. That is, power-intensive industries make up the core of the industrial specialization of the new industrial complexes in Siberia.

Investigations have shown that benefits to the national economy can be expected from the development of power-intensive industries near the Angara HPSs: for example, savings from energy inputs amount to hundreds of millions of roubles annually [4].

Research on the development of the power and industrial complexes in the Angara area was conducted simultaneously with the design of schemes for hydropower plants, to be built near these complexes. For example, the Bratsk power and industrial complex was incorporated in the scheme for the Bratsk HPS. The scheme stipulated the locations of the principal consumers and gave recommendations on how to construct the power and industrial complex. The difficulty was that both the HPS and its main consumers were to be operational at the same time. These problems were not taken up separately but were solved in a coordinated way so as to determine inter alia the following: the general conditions of the project; the necessary distribution of capital investment over the building period; the demand for principal building materials, intermediates, and machinery; the project's manpower requirements; and the necessary housing accommodation; and cultural and welfare facilities.

Studies covered the raw material resources of the Region, its railway and water transport, the development of agriculture and fishery, and settlement and environmental protection [4].

The comprehensive nature of the research was determined by the fact that the Angara Region has high quality abundant hydropower resources and, diverse mineral resources, so that the exploitation of the basin's natural resources is important to the country's development. The wide spectrum of alternative solutions, the high cost and long period required for their implementation, etc., called for an analysis of natural, social, economic, scientific and engineering factors with due regard for the Region's links with the national economy so as to optimize the regional development alternatives.

The experience gained in the USSR in large-scale, comprehensive research and development schemes, and the building and operation of HPS cascades and territorial-industrial complexes may be useful in solving similar problems in other areas.

Research and development work on a similar scale was carried out in the design of large-scale hydroelectric power stations on the Yenisei. The Krasnoyarsk HPS, with a capacity of 6×10^9 W and an annual average output of 20,000 kWh, is operational on the Yenisei River, and construction is under way of the Sayano-Shushenskaya HPS with a capacity of 6.3×10^9 W and average annual power output of 23.5×10^9 kWh [3]. The Yenisei, the Igarka and other HPSSs are being designed. Feasibility studies concerning the building of large electric power stations on the lower tributaries of the Yenisei are being carried out.

Project studies have been done on ways of coordinating the operations of the Angara and Yenisei HPSSs in the Siberian power grid. Investigations have shown that the Angara and the Yenisei Rivers have asynchronous runoffs and the regulating potentials of the reservoirs on the two rivers are unequal. Taking both facts into account, special operating conditions were elaborated for the HPSSs in the overall power grid. These conditions became known as interbasin electric compensation regulations of HPS output in a grid. Accordingly, the Upper-Yenisei HPSSs, which have relatively small reservoir regulating capacities, were placed at the lowest level of the control hierarchy and allowed to operate nonuniformly over time in keeping with the regulations that ensure a most efficient use of the Yenisei runoff for power production. The Angara HPSSs were placed at the upper level of the control hierarchy. They act as a compensator for the power output variation of the Yenisei HPS, bringing the output for the power grid to a figure that could be guaranteed with a certain degree of reliability.

Owing to the compensated operating conditions and asynchronous runoff, the total guaranteed output of the Angara-Yenisei HPS cascade has greatly increased. The amount of increase depends on the number of HPSSs that are operational. For example, with only three HPSSs of the cascade being operational, their assured output increased by over 500 million. This means that by the time the Krasnoyarsk HPS was commissioned, it was possible to reduce the capacities of the thermal power stations in the grid by this amount, saving tens of millions of roubles.

After eight HPSSs of the cascade become operational, the output figure will be as high as 1.5×10^9 W [2]. Also, apart from power production, the Angara and Yenisei water resources are used for transportation, water supply, and, in recent years, for restitution of resources. The rules governing the operation of the cascade reservoirs include provisions for meeting the needs of these non-power consumers with a given reliability level.

The systems approach which analyzed the natural, technical, and economic factors affecting the HPS efficiency in a complex water economy and joint power system of Siberia, was used in working out the operating conditions of the Angara-Yenisei HPS and their reservoirs. This has helped the Region to raise the economic efficiency of the existing HPSs.

In addition to traditional methods, some new ones have been used to elaborate and ensure the optimal regulations for the operating control of the HPS reservoirs of the cascade.

Since the water economy and power systems are probabilistic (the influx of water to HPSs being a probabilistic process), a statistical modeling of the river runoff was used for designing the optimal operating conditions for the cascades of reservoirs [1,5,6]. Although only recently developed, methods for river runoff modeling (sometimes called the Monte Carlo technique) have become widely used in many parts of the world. Studies have proven the efficiency of this technique for calculating the runoff regulation patterns for HPSs reservoir cascades over a period of many years [6]. They have confirmed the feasibility of ensuring optimal compensated operating conditions of reservoirs in the Angara-Yenisei HPS cascade and of securing the above mentioned water economy and power production effect from the interbasin electrical regulation of HPS power output in the Siberian grid.

Methods for long-term control of HPS operating conditions in the power grid have been developed and used for a number of years to implement the optimal operation schedules of the cascade. Optimization in this case is based on specific economic criteria; for finding the ultimate objective function of many variables, several iterative techniques are used (gradient technique, dynamic programming, etc.). Heuristic and mathematical methods are used to generalize the optimal operating conditions into prediction-free rules of control.

In order to reduce the size of the optimization and control problems, the principles of design and practical operation of a hierarchical structure of control of the operating conditions of the HPS cascades and reservoirs have been developed, with special reference to the Angara-Yenisei cascade [5]. Besides reducing the problem dimension, the introduction of the hierarchy made it possible to decentralize the control of some HPSs, giving them an autonomy while retaining virtually all advantages offered by the joint operation of HPSs in the power grids [2,5]. Electronic computers of different classes were used to make the calculations for elaborating and substantiating the rules for controlling the HPS operating conditions in the power grid at virtually all stages of the project and also in the actual process of operation of the HPSs of the Angara-Yenisei cascade.

Recently there has been an attempt to apply a new and rapidly developing section of the probability theory--the theory of controlled random process--to control the operating conditions of the Angara-Yenisei HPS cascade.

Control is based on a vector stochastic differential equation of water balance. The runoff is approximated by a continuous Markovian harmonized process. The analytical description of the runoff is given by an autoregressive equation for the transformation of the runoff values conforming to the Gaussian distribution pattern. Restraints imposed on control are represented by penalty functions whose sequence is chosen depending on the level of the security of the restraints concerned.

The system of stochastic differential equations describing the Angara-Yenisei HPS cascade, the objective function to be optimized, and the control function are linearized; thus it is possible to solve the problem of finding the optimum control conditions for the cascade's reservoirs by a small dimensional Riccati matrix equation. This solution requires only a few minutes on a medium-class computer [5].

Thus in the planning and development of power and other natural resources in the Yenisei basin, problems arise which because of their complexity and multiplicity of variables are within the scope of systems engineering.

The Angara-Yenisei cascade project was a testing ground for a number of new methods and techniques of research, design, building and operation of a large-scale industrial complex. These new methods and the experience gained in applying them to the Angara-Yenisei HPS cascade can be useful for planning and implementing projects on other rivers and in other parts of the country with similar natural and economic conditions.

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Water Resource Systems†

Z. Kaczmarek

Water is essential to national regional economic growth. Under certain circumstances, water development projects play a significant role in increasing economic activity. Water resources alone do not produce regional development, thus water projects should not be considered the only factor in a regional development program. Regional economic development is a complex economic and social phenomenon. Nevertheless, it has been found in many areas of the world that water development has stimulated regional growth. The Angara-Yenisei water system is an excellent example of such a situation.

As Reznikovsky mentioned in his paper, the Anagara-Yenisei river basin represents one of the world's largest water resource systems. With its mean annual runoff of about 600 km³, it is the largest water system in the USSR, producing more than one-eighth of the total river runoff of the country's area. It is therefore easy to understand the importance of the system to the whole new production complex of Central Siberia.

The relationship between *fixed* water supply and *changing* water demands in any area reflects the prevailing social and economic conditions, the availability of skills and funds for making changes, the suitability of technology as it affects the environment, and the governing administrative, organizational and judicial processes. The application of systems analysis may help in solving these problems.

As in many other new industrialized regions, the development of the Angara-Yenisei water resource system started with the construction of large hydroelectric power stations. As Reznikovsky mentioned in his paper, investigations have shown that the development of power-intensive industries in that region promises enormous benefits for the national economy. The multireservoir hydropower system may be treated as a subsystem of the Siberian industrial complex, and its construction and operation had to be subordinated to the general needs and goals of this complex.

†Comment on A.Sh. Reznikovsky, *Angara-Yenisei Hydroelectric Power Station Cascade*, in this volume.

It should be expected that further development of Central Siberia will create new problems in the field of water resources. Demands for water supply for the population, industry, and (perhaps) agriculture, will increase more or less in proportion with the level of production, and the environmental effects of water use will have to receive increasing attention. During the last decade, the world's population has become more sophisticated in its understanding of ecological processes; as a result it is aware that in many cases, past water uses and developments have produced some unpleasant and unforeseen consequences. Discussion at the 1974 IIASA Conference on the Tennessee Valley Authority pointed out examples of such dangers.

In order to achieve overall goals in water resource systems and to protect environmental quality, it seems to be necessary to do the following:

- Draw up a general plan of water resources development including hydropower production, flood control, water supply, transportation, recreation facilities.
- Understand, and be able to predict, the environmental effects that a particular water program, and the alternatives, may produce.
- Take environmental values and processes into account in selecting alternatives to reach an informed and balanced judgement as to what will best serve the national interest.

Some clarification of the links between hydropower subystems and other water resource systems in the Angara-Yenisei river basin would help to better understand the entire water situation in the above mentioned area.

Reznikovskiy has stated that a statistical modeling of the river runoff was used in designing optimal operating rules for the cascade of reservoirs. The Markovian process with Gaussian distribution has been used to model the stochastic behavior of the process. It would be interesting to know how the cross-correlation characteristics were preserved in the model, and the criteria used for the evaluation of the model. I would like to mention that IIASA's Water Group is involved in a program in the field of stochastic modeling, and in February of this year held a workshop on the improvement and evaluation of multisite, multiseason streamflow generating models.

It would also be interesting to know the optimization procedures that were used in the case of the Angara-Yenisei cascade and how the results obtained from this optimization model were used for practical day-to-day operations. Were the forecasting models incorporated into the optimization scheme?

The discussion may help to clarify these and other questions related to the unique and very interesting Angara-Yenisei water and industrial systems.

Runoff Regulation of the Angara-Yenisei
Cascade Hydropower Stations

L.S. Belyaev, V.A. Saveliev, and L.E. Khalyapin

The Angara-Yenisei cascade, which includes the Bratsk and the Ust-Ilimsk hydropower stations (HPS), is unique with respect to the capacities of these hydropower stations, their economic indexes, and the regulating capacities of the reservoirs. Table 1 gives the main hydropower characteristics of the cascade's existing HPSs, and those to be commissioned shortly [1]. Additional hydropower stations will be constructed on the Yenisei River and its tributaries, but their parameters have not been fully determined.

Because of the large reservoirs, especially at the Irkutsk and the Bratsk HPSs, it is possible to fully utilize the river runoff by reducing waste overflow to a minimum, and to redistribute the runoff in a desired manner over the short and long run. Moreover, these HPSs supply almost 50 percent of the overall power of the Siberian Integrated Power System (SIPS). The HPSs are capable of carrying out the following functions:

- Account for fluctuations in the daily load curves and control the frequency in the SIPS;
- Supply the main bulk of the emergency and operational reserve capacity;
- Act as long-term power regulators in the system by accounting for discrepancies between the increase in power consumption and the new capacities commissioned in the SIPS; and
- Meet the needs of other water users and consumers such as water transport, fisheries, and city water supplies.

Since the SIPS will be linked with other power systems (for example Kazakhstan, and in the European part of the country), the influence of the Angara-Yenisei HPSs will naturally expand.

To fulfil these functions, it is necessary to regulate the runoff, taking into account the potential use of the runoff in planning further development of the SIPS. This requires special hydroenergetic calculations along the following lines:

Table 1. Indexes of existing and planned HPSs of the Angara-Yenisei cascade.

HPS Hydropower Stations	River	Commis- sioning year	Design head (in meters)	Average annual runoff (in km ³)	Reservoir capacity, run- off, (km ³) (%)	Installed capacity, MW (in million of W)	Average long-term output (in 10 ⁹ kWh)	Regulation
Irkutsk	Angara	1956	26	60	46.0	660	4.1	long term
Bratsk	Angara	1961	100	92	48.0	4,600	22.6	long term
Ust-Ilimsk	Angara	1974	86	101	2.8	4,320	21.9	seasonal
Boguchany	Angara	1985-1990	65	107	2.3	4,000	17.0	seasonal
Sayansk	Yenisei	1978	194	47	14.0	6,400	23.7	seasonal
Krasnoyarsk	Yenisei	1967	93	88	30.4	6,000	20.4	annual

- Runoff regulations to determine the water power index of HPSs;
- Coordination of HPS runoff regulation with the development of the power system in the near future;
- Scheduling runoff regulation during the operation of hydroelectric power stations.

Special features of these types of calculations and methods, and their role in calculating the Angara-Yenisei cascade and the SIPS are outlined below.

DETERMINATION OF WATER-POWER INDEXES OF HPSs

The principal indexes are the guaranteed and average long-term power outputs of HPSs. These calculations are needed for designing individual hydropower stations and for long-range planning of power systems. The operational conditions of stations or the development conditions of power systems are in this case considered in a long-range perspective (five to fifteen years or even longer). In the former case these indexes are evaluated for the individual HPS, and in the latter, for the group of HPSs as a whole. The guaranteed output determines the potential contribution of HPSs to the power balance of the system in low water years. (The remaining power demand is covered by thermal electric stations.)

The average long-term power output of a HPS is a stable index. In fact, it does not depend on the development scale of the power system and, as a rule, may change only when new HPSs are built upstream thereby affecting the inflow to the reservoir of the HPS in question. The average long-term output is used for estimating the average operational (fuel) costs of the system. In view of the stochastic character of the river runoff, two such indexes are needed for obtaining an approximate solution to the problem of optimal development of the power system. The total average long-term power output of a group of HPSs depends on the composition of the group, and thus will differ depending on the development period of the system.

The guaranteed output of a group of HPSs is less stable. Usually, its value in winter (peak load) is vital for the power system. The winter output, in turn, depends on the overall conditions of annual runoff regulation (i.e., on the possible redistribution of runoff over the seasons). Accordingly, the guaranteed output of an individual HPS can vary substantially as the power system develops; for example, changes in the pattern of the annual load demand, in the structure of power generating capacities, or in the ship clearance capacity of a channel in the navigable season will affect this figure. This is even more so with the total guaranteed output of all HPSs in the system, which will depend on the system's set of stations.

Moreover, it is not the guaranteed output as such but the guaranteed capacity of all the stations that is important for evaluating the HPS contribution to the power balances in low water years. The guaranteed capacity is determined from the calculations of daily operating conditions of the power system by "writing" the respective HPS output in the daily load curve of the system. For this purpose, the daily guaranteed HPS output is determined for the peak day (usually, in December) of the year being considered, based on the guaranteed winter HPS output, and taking into account the intraseasonal and weekly fluctuations of the load curves. For this daily output, the daily operating conditions for the stations are calculated; thus the contribution of a given HPS for covering the peak load is determined. This value is the guaranteed capacity of HPSs (i.e., their possible contribution to the system power balance in low water years).

The guaranteed capacity of HPSs also depends on the daily load demand curve, which changes as the system develops and is integrated with other power systems. The magnitude of this capacity has therefore to be estimated for specific development stages of the system. In designing an individual station, one should consider the longest possible period (i.e., as long as possible in terms of forecasting future operational conditions of the HPS). For planning the development of a power system, the calculation period is determined by the plan targets.

The runoff regulation schedule of individual HPSs depends on the regulation schedules of other stations. Therefore, in evaluating the HPS water power indexes, the runoff regulation schedule has to be calculated for a whole set of stations, even when these indexes have to be found for only the individual HPS being designed.

These calculations are needed in particular for the so-called compensated runoff regulation, which is desirable because of the mistimings in the runoffs (during low water periods) of different rivers and reservoir capacities. A low runoff rate in some rivers can be compensated by excessive runoff in others, and inadequate storage of some reservoirs can be compensated by increased tapings from larger reservoirs.

Compensated runoff regulation can substantially raise the guaranteed HPS output. Calculations have shown that the total average monthly guaranteed capacity of the Angara-Yenisei cascade HPSs (including the Ust-Ilimsk and the Sayano-Shushenskaya HPSs) increases by 1,300 MW owing to compensated regulation. This yields considerable savings in capital investment for the construction of thermal electric stations in the SIPS.

To reduce the amount of labor, calculations have to be carried out on the basis of specially selected long-term hydrographs of a sufficient duration. The average long-term output of a HPS is evaluated using the hydrographs corresponding to the average water content, while the guaranteed output is obtained by using

the low inflow hydrographs with a designed integral probability (to 98 percent). In this way, instead of carrying out a large series of calculations and plotting the entire guarantee curve (or distribution function) of the HPS outputs, the long-term regulation is calculated for only selected points on the curve. This approach is justified because the HPS outputs are approximately proportional to the runoff, or, to be more exact, to its total potential energy with due regard for different heads at different HPSSs. To account for the influence of runoff distribution over the years of the calculated period, the calculations are made on the basis of several hydrographs differing by the groupings of low and high water years.

The calculation (medium and low water) hydrographs are chosen either by a series of observations or a modeled series constructed by the Monte Carlo method. This method has gained wide practice in the USSR (e.g., [2,3]). Different techniques are used in this case to take into account the intraseries correlations, period runoff distribution, etc. Long-term runoff forecasting methods that take into account other geophysical factors are being developed [4].

The Energosetiproekt Institute has been carrying out calculations of coordinated long-term runoff regulations of the hydropower stations of the Angara-Yenisei cascade. The guaranteed HPS outputs have to be evaluated often, since this parameter depends more on the HPS operational conditions than on the average long-term output. The procedure for these calculations is described in [3]. In this procedure the hydropower stations are treated separately from the thermal stations in the power system. The load curve pattern is assigned to the HPS, taking into account the time of commissioning new HPSSs and the increases in their capacities over the years of the calculated period. First, on the basis of preliminary calculations, the schedule curves (dispatcher schedules) are constructed for the reservoirs as a means of regulating the HPS output, depending on the available storage. These curves are constructed for each of the HPSSs, taking into account the coordinated runoff regulation by the HPS cascade and the role played by a particular HPS in this process. In particular, the Irkutsk and the Bratsk HPSSs which have the largest reservoirs function as compensators by accounting for the deficiencies in load of the remaining stations in the required total level. Next, specific calculations for runoff regulations are made on the basis of hydrographs corresponding to medium or low water conditions; thus the likely HPS output is evaluated. The runoff regulation patterns determined by these schedules are entered into the computer-aided calculation algorithm. These calculations give the dependence of the guaranteed output of new HPSSs on the reservoir capacity used. This dependence makes it possible to find the guaranteed output for a fixed (given) reservoir capacity, or, conversely, to find the effective storage required for a given guaranteed output. Some results of the calculations carried out for the Angara-Yenisei HPS cascade are given in [3].

In 1974, the Siberian Power Institute of the Siberian Branch of the USSR Academy of Sciences conducted calculations to evaluate the water-power indexes for the HPSS of the Angara-Yenisei cascade covering the period 1980-1995. In contrast to [3], these calculations took account of the thermal electric stations of the SIPS and the main transmission links in the system. The calculations were carried out by the computer program Angara-D based on an auxiliary function method [5] which is similar to the method described in [6]. The values obtained for the average long-term outputs of HPSS were almost the same as those calculated by the Energosetiproekt Institute. Also, the average annual guaranteed outputs were similar. The winter guaranteed outputs of the HPSS, however, were about 10 percent higher than those evaluated by the Energosetiproekt.

COORDINATION OF RUNOFF REGULATION OF THE ANGARA-YENISEI HPS CASCADE WITH THE DEVELOPMENT OF SIPS

This type of calculations, specific to the SIPS, is carried out for determining the power balances of the system in low water conditions, which is needed for planning the installation of new units at the power stations. Since the output of HPSS in the forthcoming years depends on the increase or decrease in the water level of reservoirs in the preceding years, the need arises for commissioning new power stations. The lesser the potential HPS output, the sooner the new stations have to be commissioned and vice versa. Therefore, the long-term regulation schedule for the HPS must be coordinated with the time schedule for commissioning and developing new electric stations. The procedure is outlined below.

Some development scenario for the station is considered for a period of five to ten years. The necessary input data on power demand, existing and planned power stations, water needs, and long-term runoff forecasts are prepared for this period. Several runoff hydrographs are selected, corresponding to the required designed integral probability (95 to 98 percent) of the total potential energy of runoff but differing in the energy distribution by the years of the period and by the HPS ranges. The hydrographs may be selected by the procedure described above with due regard for the long-term runoff forecasts (if any) for the period. For every hydrograph selected, the long-term runoff regulation is then assessed from the actual reservoir levels at the beginning of the calculated period. If the long-term reservoir storage is insufficient for complete coverage of the system's power balance for even one of the low water hydrographs, then this scenario is rejected as inadequate, and a new one providing earlier commissioning dates for the stations or power units should be devised.

These calculations are not intended for immediate scheduling of the HPS operational conditions. They form a part of the power system planning effort for determining the commissioning times of

new electric stations. Since the nearest time in the future is considered, these calculations must be carried out in detail, taking into account the following: long-term and annual runoff regulations; HPS development pattern, in particular, the initial storage of reservoirs; water needs and constraints on water supply; mistimings in the runoffs of the Angara and Yenisei Rivers; power demand growth patterns; development of the Integrated Power Grid System; periodic fluctuations in the capacities of available thermal power stations, including fluctuations caused by repair and maintenance; and uncertainty with respect to input data.

These calculations are currently being carried out by the Siberian Power Institute together with the Joint Dispatching Office of the Siberian Power System; the Angara-D program is being used for this purpose. The last run of calculations was carried out for the period 1976-1985, and a check was made of the power balances of the SIPS for the next three to five years.

RUNOFF REGULATION SCHEDULES OF HPSs FOR THE OPERATION OF THE SIPS

These calculations must be more detailed than those described above. Their ultimate purpose is to determine the operating conditions for the existing electric stations on annual and daily terms. In addition to the factors mentioned for the previous types of calculations, the following must be considered:

- Allowance must be made for the random nature of the runoff, including high water years;
- There must be detailed consideration of the conditions of the regulation of the HPSs during the year--e.g., navigation periods and other water constraints, repair and maintenance of the power plant equipment, and seasonal fluctuations in heat load at power and central heating plants;
- There must be an examination of the daily operating conditions of the HPSs, with due regard for the capacities of the transmission lines, the constraints on water level variations in the daily runoff regulation and so on.

Many methods have been proposed in the USSR for optimizing the long-term operating schedules of power systems including hydropower stations [e.g., 5,7,8,9,10,11,12]. These methods make use of diverse mathematical tools, and each of the techniques accounts for the random nature of the runoff differently. Many of these methods have been applied to the Angara-Yenisei HPS cascade and the SIPS.

One of the methods for determining HPS runoff regulation schedule is based on the construction of schedule curves of the reservoirs [8]. The runoff regulation calculations are carried

out for constructing these curves, while the particular operating schedule for the station is assigned directly during its operation according to the zone on the schedule curves where the actual reservoir levels fall. This method has been widely applied to the HPS of the Angara-Yenisei cascade.

In the 1960s, when only the Irkutsk and the Bratsk HPSS were in the cascade, their operating conditions were optimized by applying more exact calculation methods based on stochastic formulation and dynamic programming principles [7,12]. This approach was also used to explore the control methods for long-term HPS schedules at a number of Siberian stations [13]. However, stochastic dynamic programming is rather cumbersome where the number of HPS is large.

In 1965-1967, the Siberian Power Institute calculated the long-term runoff regulation for the Irkutsk and the Bratsk HPSS so as to determine an operating schedule for the SIPS for the next fiscal year. A special feature of these calculations was that they took into account the uncertainty in the input data about future development conditions of the IPS [10].

A series of computer programs are now available for calculating the runoff regulation of the Angara-Yenisei HPS cascade at the Joint Dispatching Office of the Siberian Power System. The Angara-D program is used to compute the long-term regulation of the runoff. These calculations are carried out several times a year for varying hydrological conditions. The results are used to design the runoff regulation schedule for the forthcoming month or three months.

In order to more accurately evaluate the pre-flood decrease and increase in reservoir storage level at the Krasnoyarsk HPS, a program has been introduced based on stochastic dynamic programming methods. Its algorithm is similar to that described in [13]. During the high-flood period, calculations are carried out several times a month to obtain complete filling of the reservoir.

The daily operating schedules for the HPSS of the Angara-Yenisei cascade and the SIPS are calculated mostly by the computer program developed at the Siberian Power Institute [14] and at the All-Union Research Institutes for Power Engineering (VNIIE) [15]. The programs of the Power Institute are based on the auxiliary functions method, and those of VNIIE on relative increments combined with gradient methods. Both methods take a detailed account of regime characteristics of the power stations, grid layout, limitations, daily load schedules of the components of integrated system, etc. Calculations with these programs are regularly carried out to determine the daily operating conditions for the HPS and for the thermal electric stations.

In general, the methods and programs for all types of calculations for the runoff regulation discussed in this paper are being continually improved as experience is accumulated, new

research is carried out, and the development and functioning conditions of the SIPS become more complex. In the near future, the SIPS will be integrated with other joint power systems and will become a part of the Integrated National Power System.

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Summary Report on the Technical Session
On Energy Systems

A.A. Makarov

Among the major subjects discussed at the session were Siberia's contribution to the country's fuel and energy resources, the energy supply system for the country, the methodological aspects of the systems approach to energy and power engineering, the control and development of the power supply, and the functioning of complex power systems.

Emphasis was placed on how the Siberian power system developed into one of the world's largest energy systems, and how the unique Siberian conditions influenced the development of the Bratsk-Ilimsk Territorial Production Complex (BITPC) and other large-scale centers in the Soviet Union.

Information was given on the development of generating units in Siberia, on the construction of high voltage transmission lines, and on the organization of joint projects at the BITPC.

The experience of the Soviet Union in planning and managing power systems was of great interest to the participants. Discussion turned to the problems both of coordinating the development goals for the Siberian power system and the national development goals, and of establishing criteria for the development of regional economies.

Presentations by W. Häfele and by P. Tsvetanov of IIASA provided excellent background on the IIASA Energy Systems Project and on future directions.* Of special interest was the work on developing methods for long-range forecasting of energy supply and demand in various regions of the world.

*For information on the material contained in these presentations and for further details on IIASA's work in the energy field, see W. Häfele et al, *Second Status Report of the IIASA Project on Energy Systems 1975*, RR-76-1, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1976, and Plamen Tsvetanov and Bernard Schweeger, *Procedures and Program for the Econometric Analysis of a Group of Developed Countries of Market Economy*, RM-76-12, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1976.

Summary Report on the Technical
Session on Water Resources

Z. Kaczmarek

As has been mentioned, the Angara-Yenisei River Basin represents one of the world's largest water resource systems. With its mean annual runoff of about 600 km³, this is the largest river system in the USSR, providing more than one-eighth of the total river runoff of the whole area of the country. It is therefore easy to understand the importance of the system to the whole industrial complex of Central Siberia.

The relationship between *fixed* water supply and *changing* water demands in any area reflects the prevailing social and economic conditions, the availability of skills and funds for making changes, the suitability of technology, and the governing administrative and organizational problems. The application of systems analysis may help to solve these problems.

Water resources management must be based on the application of appropriate methodologies. The methodological aspects of water resource studies should be taken as background for more general policy issues and decisions. All the Conference presentations on the Angara-Yenisei water resource systems form an excellent example of such an approach. The water resources problems are, in general, site-specific depending upon a large number of local factors. Most of the methods and technologies used for solving regional or nation-wide water problems are, in a sense, universal. The exchange of experiences across national boundaries enables each country to benefit not only from its own efforts, but also from those of other nations. Priority at IIASA should be given to the consideration of methodologies that will be of potential interest during the next 10 to 25 years.

The need for integrated water resource management arises from the complex relationship between the water supply and its possible uses in the given area. The analysis of such complex systems cannot be simplified because the existing relations among systems components are usually complicated. In particular, the development of water resources has a considerable influence on the entire economy of a country or region.

As in many other new industrialized regions, the development of the Angara-Yenisei water resource system started with the construction of large hydroelectric power stations. As has been mentioned, investigations have shown that the development of power-intensive industries in the Angara-Yenisei Region promises

enormous benefits for the national economy. The multireservoir hydropower system may be treated as a subsystem of the Siberian industrial complex, and its construction and operation had to be subordinated to the general needs and goals of this complex.

It should be expected that further development of Central Siberia will create new problems in the fields of water resources. Demands for water supply for the population, industry, and (perhaps) agriculture, will increase, and the environmental effects of water use will require increasing attention. During the last decade, the world's population has become more sophisticated in its understanding of ecological processes; thus there is an awareness that in many cases, past water uses and developments have produced some unpleasant and unforeseen consequences. The discussion of these negative effects at the TVA Conference held by IIASA in November 1974 may serve as an example of such a danger.

There is feedback between the physical and economic aspects of water supply and water demands. For example, it is undesirable to forecast the future water requirements on the basis of simple projections of the past water uses, because this usually leads to very high and nonrealistic estimates. New technologies in agriculture and industry may effectively reduce the demand for water, so its future use will depend largely on the availability of resources, cost of supply, and general public policies. Limitation is the mother of good management: the progress in water-related methodologies should concern methods of increasing water resources and conserving water supplies.

Discussion

Recent investigations have shown that, from an economic point of view, there is a greater potential in Siberia for developing thermal and hydroelectric energy than for nuclear energy, owing to the Region's vast water and fuel resources.

In response to a question about the export of energy from Siberia, it was pointed out that the Region has no direct obligations toward the European part of the USSR concerning the supply of large amounts of energy. There is a power connection between the Siberian Grid and Kazakhstan which delivers some of its energy to the European part of the country. In the future, these links are supposed to be expanded.

Among the major characteristics of the Siberian electric power system mentioned during the session were the following: an electric transmission line of approximately 3000 km, and a load factor of 92-93 percent; industry's power consumption is approximately 80 percent, which is expected to decrease in the future. Electric power is transmitted by power lines in both directions. The length of these lines averages from 400 to 500 km. One exception is the Bratsk-Ilimsk line, which is 600 km long.

Discussion then centered on the Bratsk storage reservoir, which has a useful capacity equal to 50 km^3 and a total capacity of 170 km^3 . Owing to this useful capacity, the Soviet Union is able to produce 30×10^9 kwh of electricity.

Studies of the production of synthetic gas and its transportation from Siberia are currently being carried out in the USSR. Although Siberia has huge resources of comparatively low-calorie brown coal, its transportation over long distances is economically practicable. Consideration is being given to using the coal for energy purposes of industrial enterprises located nearby and for the production of electric power; it is also proposed to enrich the coal in order to obtain high-calorie fuel which could be transported economically over long distances.

The question arose as to the type of models used in the case of the BITPC. It was noted that the Conference dealt with only development problems of the Complex; thus examples were given of only physical and mathematical modeling efforts that have been applied to practical problem-solving in connection with the BITPC. Investigations were carried out that confirmed the exactness of the model results. The value of the static stability coefficient was determined with an accuracy of up to 1 part per thousand and that of the dynamic stability coefficient with even greater accuracy.

Information was then requested on the procedures for determining investment coefficients. Values are determined on the basis of preliminary investigations carried out by the USSR State Committee on Science and Technology and the USSR State Planning Committee. These figures must not be considered a direct result of mathematical modeling; however, the latter results (shadow prices, experts values, etc.) are taken into account in determining these coefficients.

In the study of various aspects of development of the Bratsk Region, account was taken of those connecting factors that influence development. This is important since additional expenditures are usually involved. For example, specialized plants have been constructed to attract manpower to the Region. Also, the development of a new complex results in additional expenditures for housing, education facilities, theaters, etc. This was especially true in the case of the timber complex. Thus city budgets take into account the industrial needs of a complex.

Environmental considerations are included in the planning and designing stages of a complex. The cost associated with these considerations is usually three to five percent of the total costs.

The participants then centered their attention on the production of hydroelectric power in the Bratsk Region. The Bratsk hydropower station is fully automated, and only operators are on duty at the station. As regards the Siberian Power Grid, the control center has a computer unit for the collection and storage of information. In the very near future, the operations of the entire grid system will be placed under automatic control.

Owing to the length of the transmission lines in the Region, alternating current is used. To compensate for losses in transmission lines with the current voltage equal to 500,000 kV, horizontal condensers have been installed. Rotating compensators with hydrogenous cooling have been installed in the circle substations.

An inquiry was made about water resource planning in the Bratsk Region. It was pointed out that forecast methods are used to establish control schedules for a specific year. Possible conflict situations involving industrial and consumer water users are solved at the planning stage by estimating the demand for and the available supply of water. Regulations are worked out for the use of water, which take into account the interest of all users. When a serious conflict arises, the demand is met by supplying water from other sources that are part of the overall system.

As to the organizational aspects of the Siberian Power Grid, it was stated that the system includes eight administrative regions. Coordination of the regional system is accomplished with a view to the optimal use of water resources. A number of factors are taken into consideration such as agriculture, industry, transportation, and population.

DEMOGRAPHIC AND SETTLEMENT PROBLEMS

Population and Manpower Resources in the BITPC

V.V. Vorobyov, L.K. Zmanovskikh, and G.M. Podlinyaev

The region under investigation covers an area of 89,000 km² and includes three administrative districts of the Irkutsk Region: the Bratsk district with an area of 33,300 km², the Ust-Ilimsk district with an area of 26,900 km², and the Nizhneilimsk district with an area of 29,500 km². As of January 1, 1974, the population of these districts totaled 397,000 individuals.

The Angara Region is comparatively densely populated, 4.5 people per km², which is 1.5 times greater than the average for the entire region (3 people per km²). However, in view of the high concentration of natural resources and their large-scale development, the area has a manpower shortage. As a result, intensive development of the highly effective natural resources is impeded by a limited work force. Hence, solving the problem of manpower resources in the BITPC depends on the growth of the population, the adequate supply of a work force for developing industries, and the rational use of these resources.

DYNAMICS OF POPULATION

The population of the BITPC has increased considerably over the past 15 years (Table 1). The economic development of the region falls into three periods of population growth.

Table 1. Rural Population of the BITPC (1959-1974)
(1,000)

District	Size of population		Growth in 15 years (+) (-)	Natural growth (%)	Including mechanical growth (%)
	As of Jan. 1, 1959	As of Jan. 1, 1974			
Bratsk	54.6	53.7	-0.9	11.7	-12.6
Ust-Ilimsk	3.3	7.6	+4.3	3.0	+ 1.3
Nizhne-Ilimsk	21.2	15.1	-6.1	3.8	- 9.9
Total	79.1	76.4	-2.7	18.5	-21.2

The *first period* (1926-1939) covers the initial stage of development of the Region. The census conducted at this time provided fairly precise data on the population, major growth trends, and regularities of its dynamics. In 1926, the Region's rural population totaled 46,000, of which 29,000 were in the Bratsk district, 10,000 in the Nizhneilimsk district, and 7000 in the Ust-Ilimsk district.

During the *second period* (1939-1959), there was considerable growth of the population, particularly during the 1950s. The 1959 census showed that during this twenty year period the population in the three districts increased almost fourfold, reaching a total of 170,000, with 53 percent of it being urban. Towns and urban town-type settlements emerged, thus evidencing progress in the industrial development of the northern part of the Irkutsk Region. The town of Bratsk rapidly expanded owing to the construction of the Bratsk hydropower station and the industrial development of the Region. The construction of the Taishet-Lena Railway in 1966 resulted in the development of the town of Vikhorevka. The town of Zheleznogorsk-Ilimsky developed in the Nizhneilimsk district as a result of the development of large iron-ore deposits at Korshunovo. The workers' settlements of Vidim, Novaya Igirma, Khrebtovaya, and Shestakovo arose as a result of the construction of the railway line between Khrebtovaya and Ust-Ilimsk.

During the *third period* (1959-1973), rapid development of the Region's productive forces led to a rapid growth in urban population, towns and urban-type settlements, bringing about significant changes in the geographical distribution of the population and urban settlements.

As of January 1974, the total population reached 397,000 with 80 percent of it being urban. During the same period the population of Bratsk increased more than four times reaching 184,000 by the beginning of 1974. The population of Vikhorevka increased by more than 50 percent. The population of workers' settlements was increasing at a similarly rapid pace in Osinovka and Chekanovskoye. By contrast, the population of the Porozhskoye workers' settlement decreased when the construction of the Bratsk hydropower station was completed and workers transferred to Ust-Ilimsk. In 1965, when the construction of the Ust-Ilimsk power station began, the population of Ust-Ilimsk was 1300; in 1973, the population reached 30,000, and the Ust-Ilimsk workers' settlement was given urban status. The town of Zheleznogorsk-Ilimsky has also experienced a rapid growth of population (27,000 as of January 1974).

During the period under review (1959-1974), the rural population has not changed to any appreciable extent in the region as a whole: in 1959, there were 79,000 inhabitants, in 1974 this number declined to 76,000; their share in the total population has decreased from 46 to 20 percent.

Significant changes in the geographical distribution of the rural population and industry have taken place as a result of the Bratsk water reservoir. About 130,000 people moved to a new uninhabited area. In place of the 249 old populated localities which were flooded, 68 modern settlements with a variety of public and cultural services have been built. Hundreds of thousands of square meters of living space, more than one hundred schools, shops, dozens of clubs, preschool children's facilities, medical institutions, canteens and other cultural and public service buildings have been constructed. Industrial buildings have been erected on the new state farms.

As preparations got under way for the flooding of the bed of the Ust-Ilimsk power station, 34 industrial enterprises, about 2000 houses, 1000 state farm buildings, and other facilities were moved to new territories. The Nizhne-Ilimsk district has 20 new industrial forestry centers, new settlements and three state farms with modern production, cultural facilities, and social services.

In the past 15 years, the population of the Bratsk-Ilimsk Territorial Production Complex (BITPC) has increased 2.3 times, the urban population has grown 3.5 times, and the rural population has declined by 3.5 percent. The network of urban-type settlements in the BITPC now includes four towns--Bratsk, Vikhorevka, Ust-Ilimsk, and Zheleznogorsk-Ilimsky--and eight urban-type settlements. Two-thirds of the total population of the BITPC, are concentrated in four towns including 46 percent in Bratsk, 8 percent in Ust-Ilimsk, 7 percent in Zheleznogorsk-Ilimsky, and 5 percent in Vikhorevka. The eight urban-type settlements account for 15 percent of the total population, while the rural localities account for 19 percent.

The modern structure of the network of urban settlements reflects the stage of industrial development of the BITPC, the economic development of new territories, and the use of their natural resources. Bratsk plays a major role in the development of new industrial centers, towns, and urban-type settlements in the BITPC.

Age and Sex Composition of the Population

This is an important consideration for the study of the quantitative and qualitative composition of the population and manpower resources, labor reinforcement of the economy, and also drafting national economic plans for the short and long term.

There is a greater number of men in the Irkutsk Region, whereas in Bratsk and the towns of Zheleznogorsk-Ilimsky, and Vikhorevka, there is an equal number of men and women.

The study of social and demographic processes has shown that the Irkutsk Region has a favorable situation with respect to the sex and age composition of the population. The number of people

under 15 is more than six times the number of pensioners, while the share of active population considerably exceeds the corresponding figures on the nation and regional levels, particularly for the towns of Ust-Ilimsk and Zheleznogorsk-Ilimsky. The percentage of young people (16-29 years) is also high. (Age groups are classified as follows: young--under 30; middle age--30-49; old age--50 and over.)

Studies have shown that a high percentage of the population is composed of young people. This tends to lower the age indicator of the population structure and to raise the marriage and birthrates. Thus we can conclude that on the whole the structure of the population of the BITPC has a favorable effect on the reproduction of the population and the formation of manpower resources.

Natural Growth

Natural growth occupies a leading place in the general population growth. The determining factor of growth is the migration influx of population, coupled with a high natural growth.

The birthrate has undergone considerable changes in recent years. The decline in the birthrate is universal for the country as a whole and the Irkutsk Region. During the period 1959-1972, the birthrate in the areas under review declined to about 1.5 times its former level. In 1959, the birthrate throughout the country was 25 births per 1000 people, in the Irkutsk Region it was 27.3 births per 1000, and in the BITPC, 32 births per 1000; in 1972 it declined, respectively, to 17.8, 18.7 and 20 births per 1000.

The recent decline in the birthrate was due to a range of social and economic factors including urbanization, the active participation of women in social production and cultural life, the number of young students, and the constant growth in the material and cultural requirements of the population.

The decline in the birthrate in the Irkutsk Region was accompanied by a considerable lower mortality rate. In the Soviet Union, the mortality rate coefficient is the lowest in the world; in the Irkutsk Region, especially in the towns and districts, it is still lower.

During the period 1959-1972, the mortality rate for the country as a whole was 8.5 deaths per 1000 population, in the Irkutsk Region it was 7.7 deaths per 1000; the figure declines to 4.5 in Bratsk, 4.7 in Ust-Ilimsk, and 4.4 in Zheleznogorsk-Ilimsky which is about half the national average.

A comparatively high birthrate and low mortality rate in the Region account for the high "natural" population growth rate. While natural growth in the country as a whole is 9.3 per 1000

population, the figure for Zheleznogorsk-Ilimsky was 22.0 per 1000 or nearly three times the national figure, and for Bratsk it is 15.6 per 1000 or 60 percent higher than the national figure. Natural growth accounted for one-third of the population increase in 1959-1970; the other two-thirds were the result of migration.

The level of natural growth in the districts of the BITPC exceeds the regional average, thereby guaranteeing the growth of the population and the replenishment of manpower resources to a substantial degree.

Migration

Migration also plays an important role in the population growth of the BITPC, since it is closely connected with the development of the productive forces and the territorial changes resulting from the development of new areas. Migration is largely governed by the plan and is closely connected with the movement and redistribution of manpower and the formation of population and manpower resources.

In the BITPC during the period 1959-1973, the population grew by 230,000, of which 79,000 were the result of natural growth and 151,000 through migration. The increase in manpower was almost exclusively the result of migration from other regions of the country.

Thus, during this period migration was responsible for an increase of 106,000 in the Bratsk population or 75 percent of the total increase, while the remaining 25 percent was accounted for by natural growth. In Ust-Ilimsk, migration was responsible for a population increase of 26,000 or 87 percent of the total population increase, while natural growth contributed only 13 percent. In Zheleznogorsk-Ilimsky, the respective figures were 20,000, 78 percent, and 22 percent. In Vikhorevka the contribution of migration and natural growth to the population increase was equal. Migrants were also a major factor in the population growth of urban-type settlements. The migration influx contributed 57 percent to the total growth, while natural growth accounted for 43 percent.

An analysis of the processes of rural population growth shows that natural growth played the predominant role.

The BITPC is among the regions that has a great need for manpower. This fact tends to attract the population. There are some counteracting factors, such as severe natural and climatic conditions and low living standards as compared with the more developed areas of the country.

Surveys conducted at various enterprises of the Region show that the main reason for the out-migration and the turnover of the work force is the inability of people to adapt to the local

climate. According to the findings of the Irkutsk Institute of the National Economy, about 17 percent of the people leaving the Region do so for this reason [1]. The second reason is inadequate housing and shortcomings in the organization of cultural and domestic life.

Manpower Resources

Manpower includes people of working age--men in the 16-59 age group, and women in the 16-54 age group, as well as employed people of the older age group and juveniles under 16.

The influx of young workers is the major characteristic of the growth of population and manpower resources in the BITPC. Thus in 1962-1965, the Bratskgesstroi building organization enrolled about 60,000 people, many of whom lacked qualifications. Vocational training centers were therefore set up. About 30,000 new workers were trained; about 20,000 finished courses at the center.

Courses were given in advanced work methods that corresponded to the present stage of technological progress, and instruction was offered in allied trades. The well developed training programs provided timely reinforcement of skilled personnel for the building projects and enterprises of the BITPC.

Annually about 3000 workers, engineers, and technicians of the Bratsk aluminium works attend various advanced training courses within the framework of the economic education system. A total of 2382 workers, engineers, and technicians completed the courses offered by the center, and over 1000 engineers and technicians are attending institutes and technical schools.

Additional staffing of various sections of industry with specialists was generally carried out by engaging graduates of institutes and technical schools (35-40 percent) and through the selection of personnel among people migrating to construction sites on their own initiative (60-65 percent).

After various work assignments were completed at the Bratskgesstroi, groups of builders were sent to other construction projects, such as the Ust-Ilimsk hydropower station, the Bratsk timber industrial complex, and the Bratsk aluminium works. Material and moral incentives have been used to induce skilled and experienced personnel to remain in this Region.

The concern of both the Communist Party and the Soviet Government for the well-being of workers in the northern districts of the country found its concrete expression in the Decree of the Presidium of the USSR Supreme Soviet which treated the Bratsk, the Ust-Ilimsk and the Nizhneilimsk districts on an equal basis as the districts of the Far North. People living and working there are granted a number of benefits, the most substantial

being district wage coefficients ranging from 1.3 to 1.6. About 10 percent wage allowances but not more than 50 percent of monthly wages are paid for every year of service in these districts. People who work more than two years receive an additional twelve-day leave and free vacation travel. In cases of temporary disability enterprises pay an allowance equal to 100 percent of the actual wages earned by the worker. Persons who work in the region for 20 years or more may be pensioned five years earlier than the statutory pension age. Thus, men can retire at the age of 55 with a service record of 25 years and women at the age of 50 with a service record of no less than 20 years.

At the BITPC, more than one million square meters of housing has been set up as well as a broad network of social, cultural, and service facilities. The complex has its own television center, and a General Engineering Department has been set up at the Polytechnical Institute there. Special attention is given to providing the population with adequate recreational and rest facilities.

During the past decade less people were engaged in social production. This is viewed as a positive factor, since local manpower resources, mainly the second and third members of families, are being more rationally used. The development of light industries is an integral part of the overall development of the district's economy. The utmost use of local manpower resources contributes to the reduction of manpower turnover, and provides for greater satisfaction of the requirements of the population for consumer goods, and raises general living standards.

The further provision of cultural and public services envisaged by the Directives of the 24th Congress of the CPSU will help to increase the supply of manpower in social production in the Region. The development of the Ust-Ilimsk Industrial Region and the construction of the Baikal-Amur Railway will have a long term effect on the growth of the BITPC.

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Dynamics, Prognosis, and Planning of
Population Changes in the Bratsk-Ilimsk Area†

A. Rogers

This paper describes the current population situation in the Bratsk-Ilimsk region, setting it in the context of past rates of natural increase and migration in that region. The region may be characterized as a rapidly growing urban center which receives a substantial flow of young migrants from its rural hinterland and from other urban centers. Their presence creates a relatively young population and this in turn leads to a higher average rate of birth and migration and a lower than average rate of death. In my comments on this paper, I would like to indicate how this description of the current demographic situation might be sharpened and expanded in a way that would be useful to planners concerned with the future development of the region. I shall structure my comments around three major points: dynamics, prognosis (forecasting), and planning.

DYNAMICS

The evolution of every regional human population is governed by the interaction of births, deaths, and migration. At any given moment its crude regional growth and component rates are all determined by the interaction of its regional age composition with the current age-specific schedules of fertility, mortality, and geographical mobility. Thus it is important to recognize the influence that the mean age of a population has on its crude rates.

Consider the age-specific profiles of fertility, mortality, and migration that are set out in Figures 1, 2, and 3, respectively. These schedules may be aggregated to yield crude component rates by weighting the individual rates at each age with the proportional age distribution of the population in question. Several such distributions are presented in Table 1 and illustrated in Figure 4. For the same schedule one may obtain completely different crude rates by using different age distributions as weights.

†Comment on V.V. Vorobyov, L.K. Zmanovskikh, and G.M. Podlinyaev, *Population and Manpower Resources in the BITPC*, in this volume.

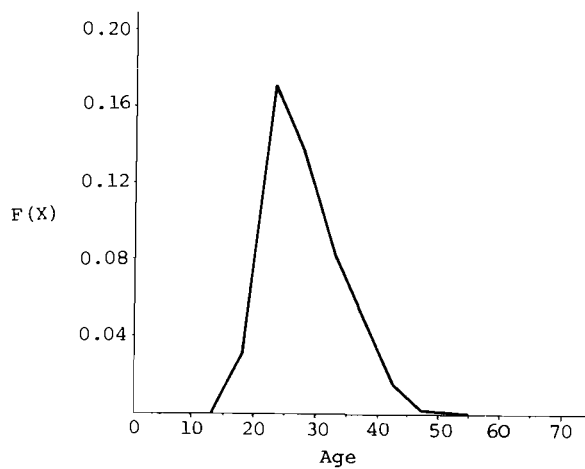


Figure 1. Age-specific birth rates of the female USSR population: 1972-73.

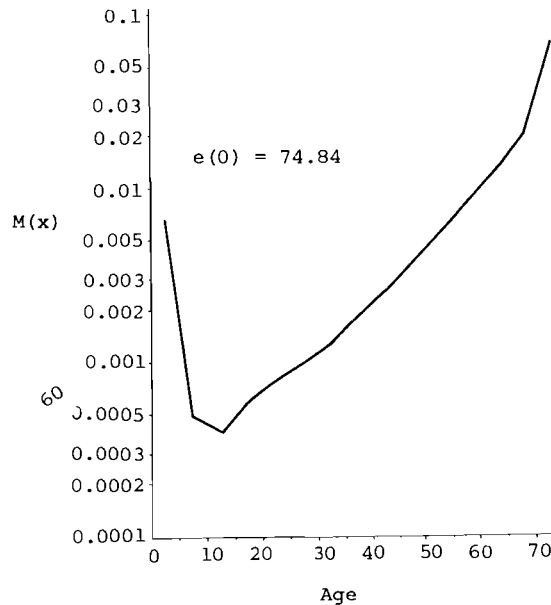


Figure 2. Age-specific death rates of the female USSR population: 1972-73.

Population by Age Group	In-Migration (%)	Out-Migration (%)
Total	100.0	100.0
0-15 years	11.0	9.0
16-19 "	21.4	24.2
20-24 "	31.2	28.0
25-29 "	9.0	10.1
30-34 "	9.7	10.6
35-39 "	4.7	5.0
40-44 "	4.2	4.3
45-49 "	2.1	2.1
50-54 "	1.2	1.2
55-59 "	1.5	1.4
60 and older	3.8	3.8
Age not indicated . . .	0.2	0.3

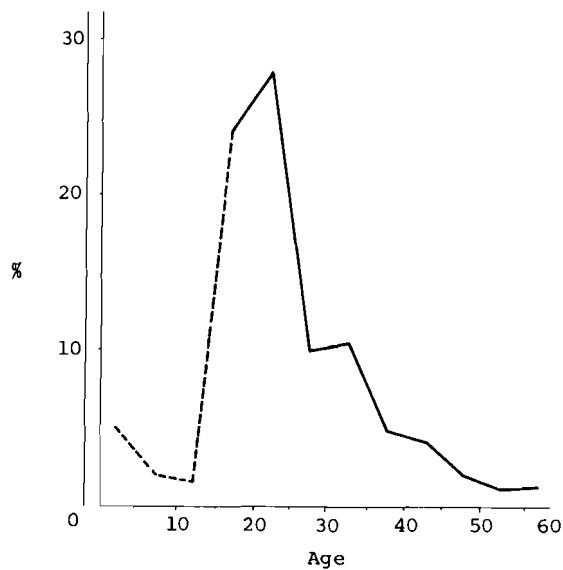


Figure 3. Age profile of USSR migrants, 1970.

Source: Rogers (1976).

Table 1. Age compositions of stable populations for different values of the annual rate of growth and following the mortality schedule of the 1958-59 life table for the USSR population.

Age Groups	-0.010	-0.005	0	0.005	0.010	0.015	0.020	0.025	0.030
0	0.94	1.16	1.42	1.69	2.01	2.36	2.74	3.11	3.51
1-4	3.78	4.60	5.53	6.56	7.67	8.86	10.10	11.40	12.72
5-9	4.89	5.84	6.86	7.96	9.10	10.27	11.46	12.64	13.78
10-14	5.13	5.95	6.83	7.72	8.62	9.48	10.32	11.10	11.81
15-19	5.36	6.08	6.80	7.50	8.16	8.76	9.29	9.75	10.11
20-24	5.59	6.18	6.75	7.26	7.70	8.06	8.34	8.54	8.64
25-29	5.82	6.28	6.68	7.01	7.25	7.40	7.47	7.46	7.36
30-34	6.06	6.36	6.60	6.75	6.82	6.79	6.68	6.51	6.26
35-39	6.27	6.43	6.51	6.50	6.39	6.22	5.96	5.66	5.32
40-44	6.48	6.59	6.40	6.23	5.98	5.66	5.30	4.91	4.49
45-49	6.66	6.49	6.25	5.93	5.55	5.13	4.69	4.23	3.86
50-54	6.77	6.45	6.05	5.60	5.11	4.61	4.10	3.61	3.15
55-59	6.79	6.30	5.77	5.21	4.64	4.08	3.54	3.04	2.59
60-64	6.65	6.03	5.38	4.73	4.11	3.53	2.99	2.50	2.07
65-69	6.29	5.55	4.84	4.15	3.52	2.94	2.43	1.99	1.61
70-74	5.61	4.81	4.10	3.44	2.84	2.32	1.87	1.48	1.17
75-79	4.56	3.83	3.18	2.59	2.09	1.66	1.31	1.02	0.78
80-84	3.22	2.64	2.13	1.70	1.33	1.03	0.79	0.60	0.45
85-89	1.87	1.46	1.18	0.92	0.70	0.53	0.40	0.29	0.21
90-94	0.89	0.69	0.53	0.40	0.30	0.22	0.16	0.12	0.08
95 and older	0.37	0.28	0.21	0.15	0.11	0.09	0.06	0.04	0.03
100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
0-19	20.10	23.63	27.44	31.43	35.56	39.73	43.91	48.00	51.93
20-59	50.44	51.08	51.01	50.49	49.44	47.95	46.08	43.96	41.67
60 and older	29.46	25.29	21.55	18.08	15.00	12.32	10.01	8.04	6.40
100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

For example, the crude death rate of the USSR population under the mortality regime defined by Figure 2 would be relatively high (15.4) if the population's age composition were the one in the first column of Table 1 (an old age composition) and it would be relatively low (4.6) if the age composition was that of the last column (a young age composition). Thus it is difficult to assess statements such as:

In the Soviet Union, the mortality rate coefficient is the lowest in the world and in the Irkutsk region, especially in the towns and districts of the region under review, it is still lower.... In the country as a whole the mortality rate is 8.5 deaths per 1000 population, in the Irkutsk region it is 7.7 on the average, whereas the figure drops to 4.5 in Bratsk, 4.7 in Ust-Ilimsk, and 4.4 in Zheleznogorsk-Ilimsk or almost half the country-wide average.

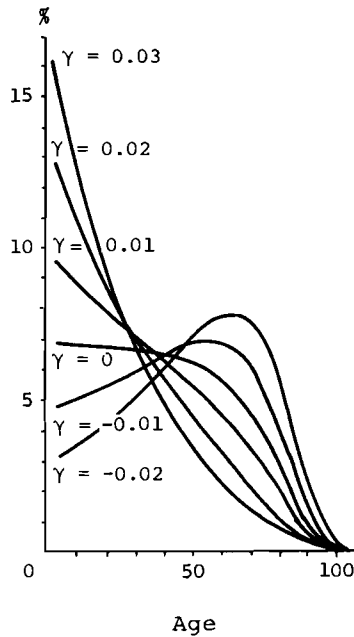


Figure 4. Age compositions of stable populations for different values of the annual rate of growth (based on the USSR life table for 1958-59).

The same argument may be used to show that the higher than average fertility and migration rates in the Bratsk-Ilimsk region are also primarily a consequence of its young age composition. Notice that both in- and out-migration rates should be high. The high in-migration rates arise because it is the young labor force that is being attracted to the region. The high out-migration rates arise because this same young population tends to be very mobile (as Figure 3 shows) and therefore is likely to move once again. Thus if:

The influx of young workers is the main specific feature in the formation of population and labor resources in the Bratsk-Ilimsk TPC,

then it is not surprising that:

...the settlement of the population coming here is complicated by such counteractive factors such as ...high migration mobility, fluctuation in the work force supply....

The point I wish to make is that this will always be the case so long as the Bratsk-Ilimsk population is a young population with a low mean age because this behavior is a logical consequence of human population dynamics. Thus if the region is to grow rapidly in population size, considerable effort will have to be made to increase the flow of in-migrants and to

maintain this flow in order to continuously replace those former migrants who will leave. How to do this and how much the increase should be in order to meet the manpower demands of the region lies in the province of prognosis and planning. These are the next two points about which I wish to comment.

PROGNOSIS (FORECASTING)

Most consistent forecasting models of regional demographic and economic growth have a relatively simple conceptual structure. The demographic submodels develop projections of the supply of manpower; the economic submodels forecast the expected demand for labor. Imbalances between the two projections activate forces, such as migration and changes in labor force participation rates, which tend to move the demographic-economic system toward an equilibrium. Proper planning can help ensure that this equilibrium is reached in an efficient and equitable manner.

Let me be more specific now and suggest a possible framework which I have found to be particularly useful. Assume that we have available a dynamic input-output model of a regional economy of the form:

$$x(t) = Ax(t) + B[x(t+1) - x(t)] + y(t) \quad . \quad (1)$$

In such models, total output at time t (denoted by the vector $x(t)$) is divided between interindustry demand, investment demand, and final demand (i.e., the three quantities summed in Equation (1)).

Assume, further, that we have developed a matrix population projection model of the form:

$$w(t+1) = Gw(t) \quad , \quad (2)$$

where $w(t)$ is a vector describing a regional population disaggregated by age, and G is a population growth matrix that projects the population forward by one interval of time.

In the past, economists have often used the model in Equation (1) to project total output by sector and generally have assumed that the labor manpower which would be needed to produce this projected total output would be available.

Demographers, on the other hand, have often taken the opposite extreme and have used the model in Equation (2) to project total population by age and sex, under the implicit premise that economic conditions and relationships would remain unchanged.

Table 2 illustrates what can happen under either extreme and compares those results with ones that arise from yet a third approach--one that I call the consistent projection approach and which is illustrated in Figure 5.

Table 2. Aggregate projections of the West Virginia economy.
Source: Rogers and Walz (1972).

Projection	1965	1975
<i>Independent population project</i>		
Total population	1812000	1751000
<i>Independent economic projection</i>		
Total gross output*	19.8	30.5
Gross state product*	4.6	6.9
Total population	1812000	2035000
Total employment	477600	563000
Labor-force participation rate (%)	47.8	52.2
Unemployment rate (%)	6.8	4.3
<i>Consistent projection</i>		
Total population	1812000	1730000
Total gross output*	19.8	28.6

*Billions of dollars at 1965 prices.

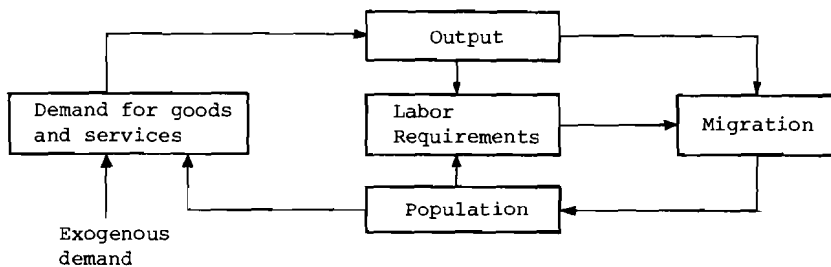


Figure 5. Conceptual linkage of the supply and demand for labor growth models.

In Table 2, the consistent projection of the population and economic growth of the state of West Virginia shows a total population which is less than projected by either of the other two approaches. Total output also is less than projected by the "pure" input-output model (i.e., when that model is not linked to the demographic model). The point that I wish to emphasize is simply this: one should not model a demographic-economic system either from a purely economic (manpower demand) oriented point of view, nor from a purely demographic (manpower supply) perspective. The two need to be linked together and such a marriage of demography and econometrics I shall call *demometrics*. Demometric models ultimately will provide planners with the necessary tools for understanding the demographic-economic systems with which they have to deal in helping decision-makers to formulate human population settlement strategies and policies. This is the last point which I wish to address.

PLANNING

For several years, considerable interest has been shown by mathematical economists in the potential utility of the optimal control methodology pioneered by such prominent international scholars as Pontryagin of the USSR and Solow of the USA. The fundamental idea of these new developments is simple, even though its implementation is terribly complex and difficult. The idea is that one should identify an objective, a set of instrumental and target variables, and a model which describes the behavior of the system in question. The instrumental variables are to be manipulated so as to achieve a set of feasible targets at, for example, minimum cost. This approach has caught the fancy of scores of young economists and dozens of recent doctoral dissertations are its current yield.

The optimal control approach also may be applied to demographic and demometric models, and we at IIASA are currently working on this aspect of migration and settlement problems, connecting it with other related topics such as population dynamics and demometrics. In its simplest form, we can introduce into our model of Equation (2), an intervention vector, $u(t)$ say to obtain:

$$w(t + 1) = Gw(t) + u(t) \quad . \quad (3)$$

Now, given a target population w^* for our system, we can begin to ask, of the model, questions such as:

- Is the population target feasible?
- If the target is feasible, how should we manipulate the instrumental variables (in this case, the vector $u(t)$), to achieve it while satisfying some predefined constraints and specific objective function?

Answers to questions such as these are of paramount importance in developing strategies for migration and human settlement policies and for testing the probable consequences of alternative courses of action.

CONCLUSION

The paper by Vorobyov, Zmanovskih, and Podlinyaev presents a most interesting problem for systems analysts at IIASA. It poses a problem that requires an interdisciplinary (or rather a multidisciplinary) systems analysis approach toward the resolution of the important and universal problem of integrated regional demographic-economic development. This is an activity that IIASA is particularly well equipped to carry out, and we are grateful to the three authors for providing us with an additional incentive to do so.

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Development Patterns of Linear-Node Structures of
Territorial-Production Complexes in Developing Areas

K.P. Kosmachev

INTRODUCTION

Economic geography is a science that investigates spatial systems of economies of different types and scales. Economic development of territories is a prerequisite for building up such systems. Development "embraces all permanent changes in the geographic environment, especially all permanent installations constructed by man's efforts" [1, p.66]. As the economic units in an area grow in number and complexity, the spatial systems pass from one state to another. Therefore we can regard the economic development of the area as a major geographical process.

The economic progress, together with other socio-economic processes, has an important bearing on the formation of the territorial-production complexes (TPC) in the developing areas that are typical of Siberia and the Far East. This process is characterized by specific, localized stages, diverse forms and directions of movement. A knowledge of these patterns is essential for controlling this process [2]. Therefore there is a need for studying the formation of linear-node patterns of TPCs in developing regions for determining future development trends.

The concept territorial-industrial complex is neither synonymous with, nor a substitute for, the more sophisticated notion of economic region. This should be borne in mind while reading this paper which is based on data on the development of the BITPC. A basis for the development of the BITPC is the Taishet-Lena Railway line, which is the western branch of the Baikal-Amur Railway Line (BAM) that has been operating since the early 1950s. This research may be useful for solving similar development problems of other regions through which the BAM will pass in the near future. The BITPC may be regarded as the main link in the system of TPCs in the BAM zone. The development of such complexes is a decisive factor in the formation of new economic regions in developing areas.

To illustrate the role of the BITPC in the region-forming process, we shall consider the whole zone where the TPC has direct influence, i.e., the Mid-Angara area. Its boundaries (Figure 1) have been delineated by Kosmachev and Losyakova [3].

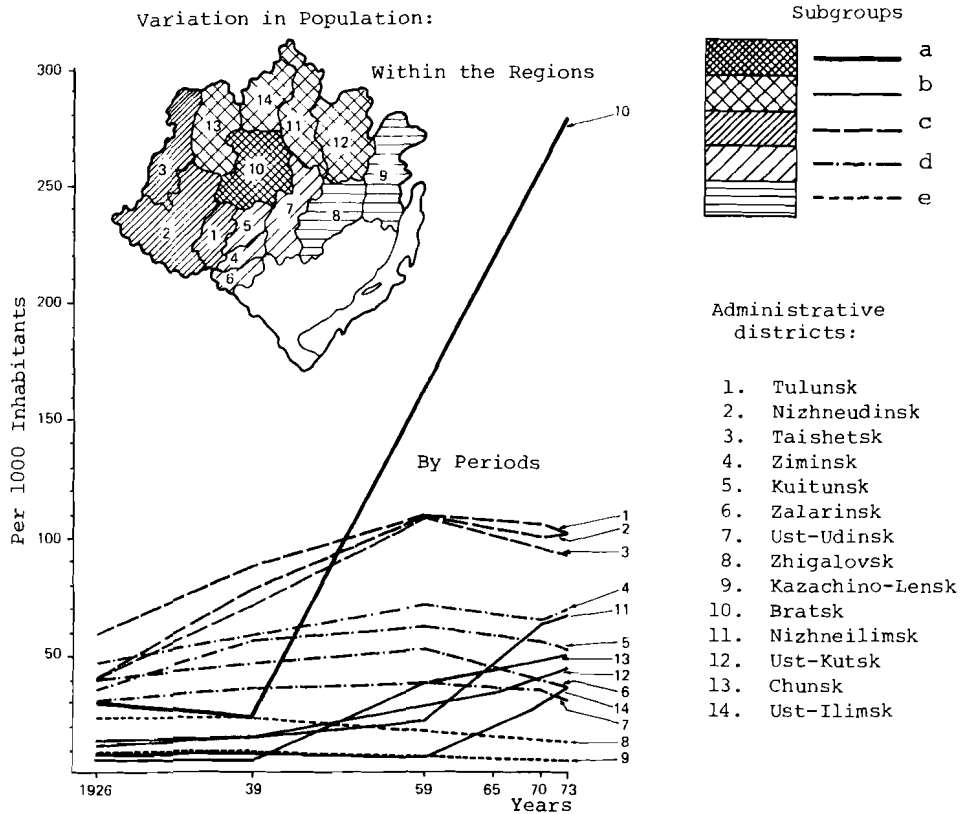


Figure 1. Settlement dynamics of Mid-Angara area.

In 1783 the first town built in the Mid-Angara area represents the initial element of the infrastructure whose development has promoted the formation of the BITPC.

LINEAR-NODE STRUCTURES OF TPCs

A TPC is a complicated (open) socio-economic system. To study this, calls for an understanding of the notion of structure--a set of elements of the system and the ways of uniting them together, in other words, "a network of links between the elements" [4, p.194]. A special place in structure belongs to spatial relations. The whole (that is, the material entity) and its parts have a certain size and extent. Some components may be larger while others are smaller, but they all occupy some definite place in the whole; moreover, they are arranged in a regular and proper manner. It is this arrangement of the parts in space and the distances between them that are vital for the stability and strength of the system [5, p.11]..

The nodes of spatial links (towns and communication lines) are the basic elements in the TPC structures and may be called linear-node structures, which in their totality constitute the "skeleton of the spatial-economic structure of a country" [6]. Hence, data on the formation of towns are particularly essential to the study of horizontal aspects of the development of linear-node TPC structures.

In this respect, graphs may be helpful since information about TPC structure can be represented on a scale "by a coherent system of symbols oriented in space, rather than by discrete symbols" [7, pp.15,16].

POSSIBLE APPROACHES TO DEVELOPING DYNAMIC MODELS OF LINEAR-NODE STRUCTURES OF TPC

Saushkin believes that "matrix mathematical models, or even groups of models, are inadequate for solving the problems of the spatial organization of TPC. Graphs and maps should be drawn to supplement these, and the graph method should be moved to the foreground" [8, p.436]. Based on this, we developed models that proceed from Bunge's statement that "specific optimal displacements give rise to specific configurations, i.e. geometry and displacements are closely interrelated in space" [9, p.244]. Under certain specific assumptions *space configurations* can yield information on the displacements which generate these configurations and the spatial links that are typical of them.

This paper deals with specific *displacement configurations* formed on the map of the Mid-Angara area by sets of urban areas. It is a graph made up of isolated nodes (zero-graph). Our task was to convert this zero-graph into a tree, since "the graph of the cheapest connecting network must be a tree" [10, p.52]. Indeed, such a network is typical of the initial stages of economic development of any territory, the Mid-Angara area being no exception.

We used a specific technique, the Wroclaw taxonomy method or the Wroclaw dendrite, for roughly determining the layout of spatial links corresponding to some configuration of the urban area. The application of this technique is described in detail by Lewinski [11].

Recently, Soviet geographers have used this method for studying the spatial organization of socio-economic systems in various parts of the USSR, including East Siberia [12,13].

Dendrite construction techniques have been used to determine, in the first approximation, the genesis of the layout of spatial links which are the principal elements in TPC structures. Special matrices were compiled on the basis of two closely interconnected indices: foundation dates of urban settlements, and distances between them. These indices were not used by the authors of the Wroclaw dendrite method.

Table 1 lists the data for analyzing the development of the city system in the period 1783 to 1956. Settlements that are more closely located have been chosen successively from the columns of the matrix (1-17). They are then connected by lines on the map (Figure 2) showing the spatial distribution of the urban settlements in the given period observing the dendrite rule: links formed earlier and links which close the network shall be eliminated [11].

In our example, settlements 1 and 11, 2 and 3, 3 and 11, 4 and 7, etc., were linked. Eventually, all urban settlements on the map will be united into one system with the characteristic subsystems. Thus for the relevant development periods we obtain graph models, prepared on the scale of the map, of the linear-node structure of the Mid-Angara (Figure 2).

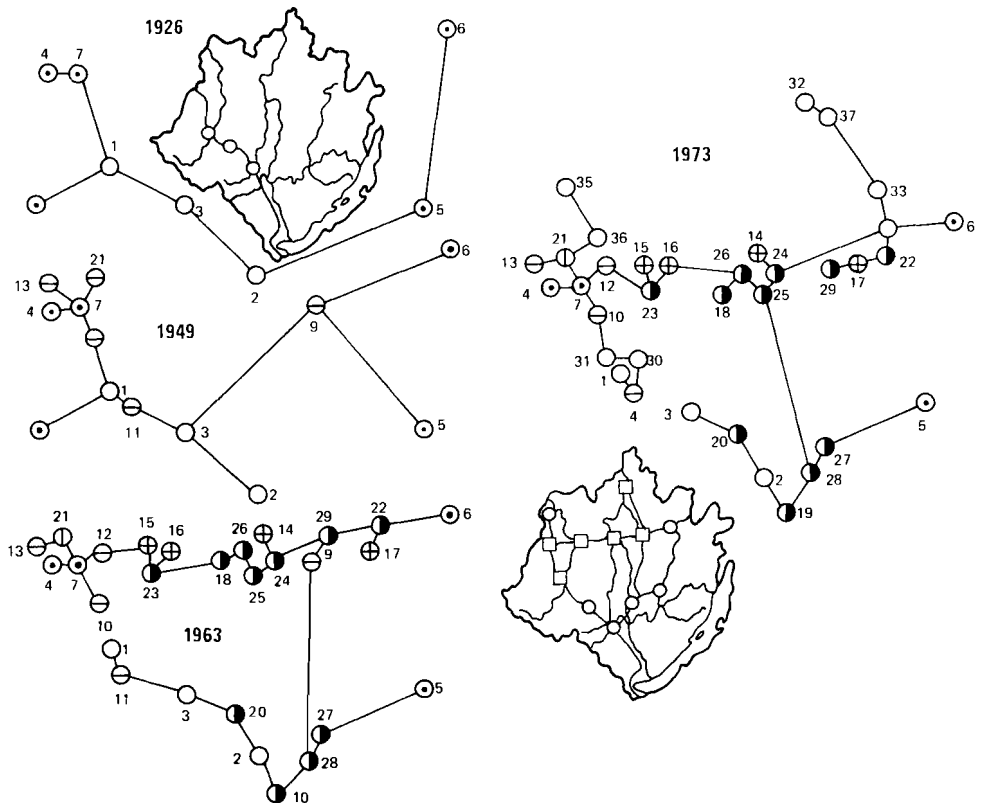


Figure 2. Development of linear-node structure in the Mid-Angara area.
(See next page for key.)

1. Nizhneudinsk	30. Atagai
2. Zima	31. Uk
3. Tulun	32. Ust-Ilimsk
4. Biryusinsk	33. Novaya Igirma
5. Zhigalovo	34. Khrebtovaya
6. Ust-Kut	35. Novobiryusinsk
7. Taishet	36. Shitkino
8. Neroi	37. Zheleznodorozhny
9. Zayarsk	
10. Alzamai	
11. Shumsk	Time period of formation of urban settlements:
12. Kvitok	○ prior to 1926
13. Uralo-Klyuchi	⊙ 1935 - 1938
14. Bratsk	⊖ 1940 - 1949
15. Oktyabrsk	⊕ 1954 - 1956
16. Chunksk	⊗ 1957 - 1963
17. Shestakovo	◐ 1964 - 1974
18. Vikhorevka	—○— isolated towns
19. Zalari	—□— groups of urban settlements
20. Kuitun	(approximate scale: 1:7 million)
21. Yurty	
22. Zheleznogorsk-Ilimsk	
23. Lesogorsk	
24. Osinovka	
25. Porozhsk	
26. Chekanovsk	
27. Ust-Uda	
28. Balagansk	
29. Vidim	

A comparison of the data in Figures 1 and 2 with the data on the regional features of the spatial organization of productive forces in the Mid-Angara area [14,15,16,17,18] showed that our retrospective graph models agreed with reality, and that significant features of the development of the "skeleton of reality" are typical of the area.

The models represent both the genesis of the linear-node pattern of the Mid-Angara area as a whole and its specific spatial economic subsystems. By 1975 four such subsystems will have been formed: central (Bratsk), western (Taishet), eastern (Zheleznogorsk-Ilimsk), and southern. Unlike the others, the southern subsystem consists of a chain of loosely interconnected urban settlements--district centers having no satellite townships. This is a sign of its delayed development, as compared with the northern subsystems which play the leading role in shaping the BITPC. The Bratsk and Zheleznogorsk-Ilimsk local groups have been functioning for about two decades. Population growth has taken place mostly in towns that are the main settlement centers. These urban settlement groups function as cores for industrial nodes whose development is described in [19,20].

Table 1. Distances between urban settlements.
(mm, scale 1:5 million)

Urban settlements*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Nizhneudinsk (1783)		46	21	27	78	93	25	20	55	15	3	28	32	47	26	27	72
Zima (1917)	46		25	70	44	79	78	57	51	58	42	68	76	55	59	58	62
Tulun (1926)	21	25		46	59	81	44	36	46	45	18	43	51	42	36	36	61
Biryusinsk (1935)	27	70	46		96	99	2	33	62	13	30	8	5	50	20	23	78
Zhigalovo (1936)	78	44	59	96		45	94	36	43	84	77	90	101	55	78	75	40
Ust-Kut (1938)	93	79	81	99	45		96	113	37	92	93	90	103	49	78	76	21
Taishet (1938)	25	78	44	2	94	96		34	60	11	28	6	7	48	18	21	76
Nerol (1938)**)	20	57	36	33	96	113	34		75	27	20	38	36				
Zayarsk (1940)	55	51	46	62	43	37	60	75		54	56	55	67	14	42	39	16
Alzamai (1943)	15	58	45	13	84	92	11	27	54		18	12	18	44	16	18	71
Shumsk (1943)	3	42	18	30	77	93	28	20	56	18		30	35	48	29	40	71
Kvitok (1949)	28	68	43	8	90	90	6	38	55	12	30		12	43	13	16	70
Uralo-Klyuchi (1949)	32	76	51	5	101	103	7	36	67	18	35	12		54	24	27	82
Bratsk (1954)	47	55	42	50	55	49	48		14	44	48	43	54	30	27	28	
Oktyabrsk (1955)	26	59	36	20	78	78	18		42	16	29	13	24	30		3	57
Chunsk (1955)	27	58	36	23	75	76	21		39	18	40	16	27	27	3		54
Shestakovo (1956)	72	62	61	78	40	21	76		16	71	71	70	82	28	57	54	

*) Figures in brackets represent the year each was founded.

**) Have not appeared in urban settlement registers since 1954.

These development features of the linear-node structure of the BITPC can be attributed to the advantageous economic and geographical position of the East Siberian industrial complex as a whole. According to the draft plans advanced by Kolosovsky, this goal was to be achieved by

...creating a double link between the southern and central areas of this zone with the Central and Southern Urals and with the central and southern European areas of the USSR: two main railway lines laid in these directions must and, in engineering terms, can have sufficient capacities to provide for two-way mass scale transport. The western radius is the backbone of the future economy of the USSR. The far-eastern radius provides the economic links between Siberia, the Urals and the Center, on the one hand, and the Far East and the Pacific coast, on the other hand....Two more radii should be mentioned: the north-eastern and the North-Yenissei. The creation and reconstruction of these communication lines and the internal network of the future East Siberian industrial complex, on the basis of latest advances in engineering, will make it possible to tap to fuller utilization of all the advantages of the economic-geographic position [21, p.30].

The importance of the BITPC in the development of the East Siberian industrial complex is reflected in its linear-node structure, which is of paramount importance in the development of interregional communications along the directions (radii) outlined by Kolosovsky.

The graph models presented here show that the linear-node structure of the TPC is highly mobile in the new development areas of the Near North. This should be taken into account by the area planners, who are generally inclined to overestimate the stability of existing planning patterns [22, p.43].

These graph models can also be useful in determining the development trends of the linear-node structure of the TPC. In evaluating such trends, specialists often confine themselves to showing on maps only the locations of the "reserve sites for the probable new towns" [22, p.170]. However, such maps fail to show the formation pattern of the framework as a whole and the individual planning axes, though this information is essential to regional planning.

We believe that the probable location of such axes in an area can be tentatively judged from an analysis of the graph models which we have suggested for the TPC linear-node structures. For example, Figure 3 shows the expected shifts in the location of principal structural elements. These shifts will largely be caused by the build-up of new urban places (point 38-40) on sites proposed by Pertsik on the skeleton map "Classification of Siberian Towns on the Basis of Area Plans According to Conditions of Long-Term Development" [22, p.170].

The analysis of these shifts shows that the linear-node structure as a whole is highly sensitive to the place and time of the inclusion of a new element. By studying these shifts, we can discover new concepts of the long-range development of linear-node structures, an important objective of geographic forecasting. This involves predicting the likely outline of the future location of "industrial and settlement units in strips most favorable for development, with communication alleys (plan axes) and their foci (plan nodes)" [23, p.9]. Further construction of the BAM and the inevitable development of new townships are bound to play a major role in the long-range development of the principal elements of the linear-node structures in this area (see Figure 3, point 40).

One can thus predict that the BITPC will greatly influence the formation of linear-node structures in adjacent areas. This must be borne in mind in drafting the spatial organization of the productive forces there.

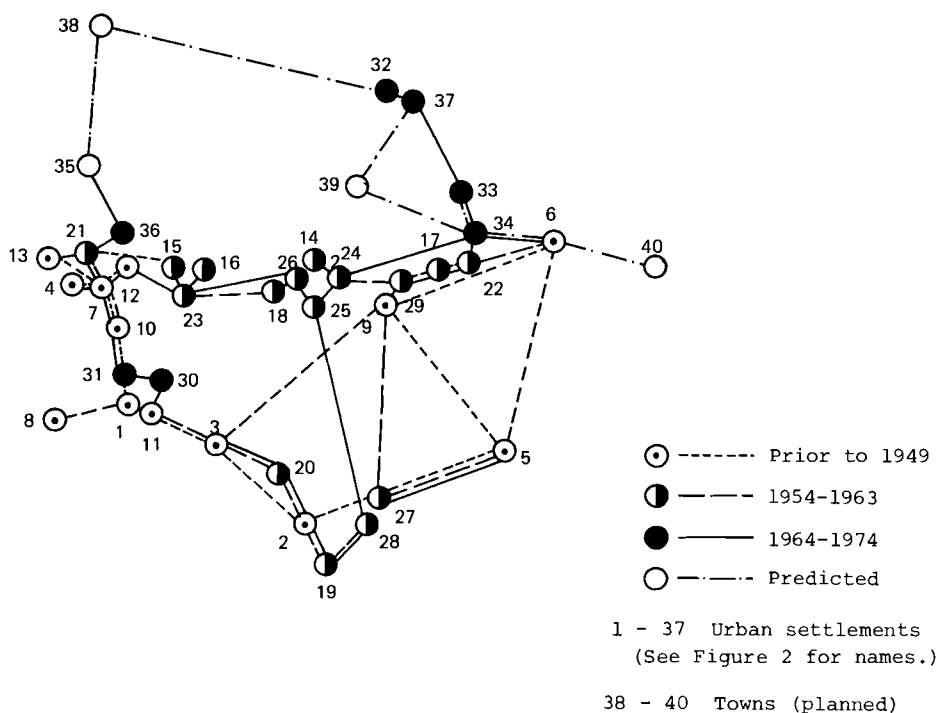


Figure 3. Model of the development of the linear-node structure of the Mid-Angara area, nodes and layout of spatial links.

Therefore, our graph models of TPC linear-node structures can provide additional information on past future development stages. In particular, they show possible changes in the directions of spatial links which will arise in the formation of new economic centers. They can be used to study the formation of regions in developing areas, as these structures function as the infrastructure framework in the development of economic regions. This problem, however, calls for additional information, particularly on spatial differences between the settlement patterns of developing areas.

REGION-FORMATION STAGES IN DEVELOPING AREAS

Kolosovsky has distinguished five stages in the development of the socialist economy of economic regions. The first stage is the current situation in reserve territories--initial stage of exploration and development of productive forces, their gross output is small and has local significance only, the population density is low and the trends of future economic development have not been established. The subsequent stages are (II) pioneer economy, (III) large-focus development, (IV) powerful economic foci, and, (V) fullfledged complex economy.

Each of the stages is distinguished by its spatial organization of productive forces. Saushkin believes that "the most significant changes in the network, trends, specialization, and place in the system of regional division of labor take place in regions at development stages II and III" [8, p.422]. Therefore, special diagrams of population dynamics are needed to identify these region-forming stages (Figure 1), which are based on censuses data from 1926, 1939, 1959, and 1970, and annual statistics for the period 1965-1973 showing the population changes in the administrative regions of the Mid-Angara area at different stages. Details on the procedures for compiling and using such graphs are given by Kosmachev and Losyakova in [3].

Indeed, analyzing the diagram (Figure 1) made it possible to outline, in the first approximation, the time limits of these periods: namely, the transition from stage I to stage II took place in the mid-1940s; from II to III, since 1950, and from stage III to stage IV, in the late 1960s and early 1970s.

The development of the forest industry began in the Mid-Angara area in the 1940s, and it changed the population pattern of a number of component regions. Spatial differentiation in the population pattern became more noticeable in subsequent years, owing to the industrialization of the area. As a result, three groups of regions with distinct population patterns were formed in the 1960s (Figure 1). In the regions of the first group, which contain the regions of the fastest population growth, the core of the TPC (regions 10, 11, 14) and the major industrial nodes (regions 12, and 13) of the Mid-Angara area were formed. The regions of groups II and III form the influence zone of the TPC

core. Considerable spatial differences between population patterns are observed in this zone (Figure 1). Analyzing these differences, we first noted a group of reserve regions (III-e), whose development depends more on the BITPC than on any other complex. In turn, regions 4-7 (II-d) because of their economic-geographic position, can be regarded as border areas delineating the influence zones of the Bratsk-Ilimsk and the Irkutsk-Cheremkhovo TICs.

These population differences in the Mid-Angara area are clearly seen in the map (Figure 1) which shows areas with similar population dynamics. With the help of such skeleton maps we can easily note groups of administrative districts with similar population dynamics. Hence the regional differences typical of these regions can be more easily identified.

We can thus say that the analysis of population processes of the Mid-Angara area with the aid of graphs and skeleton maps has identified certain trends in its spatial and temporal differentiation. The stages in the settlement process and the resulting spatial differences deserve particular attention.

Problems of developing the productive forces in the border areas, which demarcate the influence zones of the adjacent TPC, in this case the Bratsk-Ilimsk and the Irkutsk-Cheremkhovo TPCs, call for a differentiated approach.

In general, spatial differentiation with due regard for territorial differences built up during the formation of the TPC is a requisite for more efficient regional organization of productive forces in pioneer economy areas.

CONCLUSIONS

Systems of graph models based on the method described in this paper are helpful in understanding the development patterns of TPC linear-node structures. This method involves analyzing the formation of the configuration of towns and their spatial links.

Important sources of information for modeling TPC structures are maps showing the current and expected spatial distribution of towns and special matrices compiled on the basis of two closely interconnected parameters, i.e., time of foundation of urban settlement, and distances between them.

The pattern of the lines of spatial links characteristic of a particular arrangement of the node elements in TPC structures (towns) can be obtained by a proper application of the Wroclaw dendrite method.

The graph models yield new spatial and temporal information on the development of the TPC linear-node structures at various stages of region formation, including the long range. This fact

speaks in favor of using these models to forecast the development of the TPC linear-node structures for increasing the effectiveness of region-forming processes in developing areas.

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Systems Approach and Mathematical Models
For Integrative Planning of the Development
Of a New Industrial Region†

J.R. Miron

The construction of models of urban development within an interurban system or network of centers is one of the most vexing problems in location theory. How does one urban development affect the growth prospects of other areas? What role does the geometry and modal mix of the regional transportation and communication system play in shaping this effect? To what extent is such an effect socially efficient or optimal? Even if one restricts these questions to purely economic aspects, this spatial aspect of development is difficult to unravel.

Most researchers have attempted to use simplified models to get at "broad brush" answers. To obtain better answers, they would argue, one must use models that are too complicated to be feasible. Kosmachev's paper would seem to indicate that he is also of this belief. He uses a variant of the "minimal spanning tree" approach to suggest the spatial linkages existing among centers in the Mid-Angara area.* He then argues that the resulting spanning tree closely resembles the spatial distribution of the productive activity in the area.** Assuming that this resemblance constitutes a regularity, Kosmachev examines how the spanning tree would change with the introduction of the Bratsk-Ilimsk complex and what this suggests about changes in the distribution of production activity in the Mid-Angara area.

There are at least two major problems in using Kosmachev's approach. First, how do we know that the resemblance between a spanning tree and the spatial pattern of production is stable over time? At a theoretical level for example, it is not easy to see why there need to be any such resemblance. Secondly, in a centrally planned economy, the creation of productive activity at a center and the consequent effects on the levels of activity in other centers in the area should be a conscious, goal-oriented choice. However, Kosmachev's approach generates no measure of

†Comment on K.P. Kosmachev, *Development Patterns of Linear-Node Structures of Territorial-Production Complexes in Developing Areas*, in this volume.

*The Wrocław Dendrite Method is used.

**Kosmachev is vague as to how this resemblance is measured. Presumably, however, an urban center which is connected either to many other centers or to a few populous ones in the spanning tree would be larger in size.

the social desirability of such a relocation process. It is difficult, therefore, to use his model in public decisionmaking related to regional development.

What kind of an approach might represent an improvement on Kosmachev's approach? An explicit optimization model of multicentered regional development, with an appropriate emphasis on regional transportation and communications systems, would be desirable. Unfortunately, such a model is not yet available. There have been several optimizing design models produced in recent years which attempt to attack this very issue. For the most part, these are pure spatial economic models which include the multicentered central place programming model of Puryear (1975), and the single-centered model of Ripper and Varaiya (1974). A related review of optimal regional development and land-use models is forthcoming in Miron (1976).

The latter report identifies several weaknesses in current regional land-use design models. These include (a) a general reliance on static or myopic dynamic optimization instead of the long-run dynamic optimization needed for usually sequential regional development design problems; (b) a failure to explicitly consider the joint optimization of regional land-use patterns and the design of the regional transportation system; (c) a concentration on only one or two of several possible regional development design objectives; (d) an ignorance of the behavioral response of aspects of regional development not under the direct control of regional planners; and (e) no explicit consideration of the policy tools required to effect an optimal regional development plan. Because of these weaknesses, one must be cautious in the use of current programming models to answer the questions raised by Kosmachev's approach. Nonetheless, important strides in policy analysis and model development can be made by the application and extension of programming models in this research area.

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The Use of Graph Theory in Regional Development†

H.P. Young

This paper examines certain questions of regional development using graph theory. The towns of a region are represented as the *nodes* of a graph, and the *edges* represent lines of communication, presumably roads, for the most part, each edge being weighted by the distance between the nodes that it links. The author portrays the spatial pattern of settlement in a region by focusing on a *minimal weight spanning tree* in this graph, that is, a set of edges in the graph that meets every node (town), is connected, contains no circuits, and has the smallest total weight of all graphs satisfying all the above.

There are several fundamental questions; first, how to *find* a minimal weight spanning tree in a given graph (there may be more than one), and second, how to *interpret* the meaning of this graph in the context of regional development.

The first question is dealt with by applying an algorithm which Kosmachev calls the Wroclaw Dendrite method. The algorithm appears to be "successively select edges of least weight from the graph, subject to the condition that no circuits are formed; stop when a connected spanning set of edges is obtained".

This method always leads to a minimal weight spanning tree in a connected graph G. This result was proved by Kruskal (1956), and the algorithm described above is known in the mathematical programming literature as *Kruskal's algorithm*. It would be interesting to learn the origins of the Wroclaw Dendrite method in the USSR.

From a methodological standpoint the Kruskal algorithm is an interesting optimization procedure. There are several variants of the algorithm which are in fact computationally quicker. One alternate approach has been suggested by Prim (1957). Prim's method is inductive and may be described briefly as follows:

- Pick any node *v* of the graph and let *e* be an edge incident with *v* having least weight;

†Comment on K.P. Kosmachev, *Development Patterns of Linear-Node Structures of Territorial-Production Complexes in Developing Areas*, in this volume.

- "Shrink" the edge e to a single node. If this results in a pair of edges between two nodes, throw away an edge of the pair having the greatest weight;
- Continue until one node is left. Then the shrunk edges constitute the required spanning tree in the original graph.

Prim's algorithm is computationally more efficient than Kruskal's (i.e., the Wroclaw Dendrite), particularly for large graphs. The difficulty with Kruskal's algorithm computationally is in checking at each stage whether circuits are formed (something which for *small* examples can be easily done visually). It should be noted that an even more efficient algorithm has been developed by Berge and Ghouila-Houri (1965).

The second basic question, which does not appear to be resolved in Kosmachev's paper, is how the minimal weight spanning tree (or in the author's terminology the *linear node structure*) is to be used once it is obtained. Historically, changes in the linear-node structure for a region suggest possible future patterns of development. In fact, the author's Figure 2 illustrates this historical sequence and in Figure 3 some "predictions" are shown. But the rules are not given for obtaining the predicted changes from past data. The author states that "we believe that the probable location of (communication) *axes* in one or another area can be tentatively judged from an analysis of graph models". It would be enlightening to know what rules or principles are to be employed for making such judgments.

A further question arises relating to the validation of the model, Kosmachev stating that the "graph models ... agreed with reality", and "such a network is typical of the initial stages of economic development". Does the author mean that the minimal weight spanning tree predicts where roads will and will not be built? Some clarification of this point is needed.

In summary, Kosmachev has introduced an interesting methodological tool in graph theory for describing trends in regional development. What remains is to show how this descriptive tool can be systematically used for predictions by planners.

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Medical-Geographic Problems in the Formation
Of Territorial-Production Complexes in Siberia

B.B. Prokhorov

TASKS OF MEDICAL GEOGRAPHERS

Regional planning plays an important role in the economic development of new territories. In project planning much attention is focused on population growth, population adaptation, and the medical-geographic situation. For this reason medical geographers participate in drafting regional plans, and information on this type of cooperation for various regions of Siberia is given in [1,2,3,4].

Regional plans take into consideration three basic factors about the territory concerned: natural conditions, economic and living conditions, and the population.

Population appears here in a dual role. On the one hand, all work is done for the good of man, his health being one of the criteria of the quality of regional planning. On the other hand, population is an object of study. In this process, the first two factors are considered dynamic, since regional planning alters economic and living conditions that inevitably involve changes in natural environment.

For a sparsely populated territory it is difficult to foresee the possible effects of local conditions on the health of new inhabitants. A study of migration processes and the experience of population settlement in priority areas yields information about the type of people who settle there. The calculations of Soviet demographers and socialologists show that 70-85 percent of the migrants are of able-bodied age, the largest number being in the 20-24 age group. Over one-half (about 60 percent for the USSR as a whole) of the male migrants are under 30 years.

The planned region or each of its internally homogeneous sectors may be treated as a sanitary-ecologic system (SES). We will define this system as a territorial complex with a certain health standard and a specific district pathology influenced by the ecological situation.

Modern methods of medical geography are not always adequate for such a complex formation as SES. Therefore, efforts are often concentrated first on the study of the subsystems which can be viewed as sufficiently complex systems. These subsystems include the following: SES climate, SES soils, SES biota, SES

natural waters, SES economy, SES social and living infrastructure, and SES sanitary and hygienic situation. The subsystems can be gradually integrated into more complex systems.

When sufficient data have been accumulated, the initial system (the megasystem) can be described. Currently, work is under way to build models mostly graphical and matrix of such systems [5].

Such models are useful for planning improvements in the external environment and also for estimating costs of sanitation measures, which are important for determining the prospects of development and settlement of any territory.

Improving the external environment means eliminating or neutralizing its adverse effect on the health of the population. Work is conducted in two directions: improvements are made to the natural environment (geosystems), and to the existing economic and social environment. In optimizing geosystems, special attention is devoted to protecting the population from pollution and, in a number of cases, to improving components of the geographic environment such as natural waters, soils, plants, and the surface layer of the atmosphere. In addition, plans are made for exterminating pathogenic organisms in the geosystems (e.g., parasitic worms, pathogenic protozoa, fungi, bacteria, and viruses).

Of primary importance to the building of communal and industrial projects is the need to eliminate pollution and to upgrade the environment. This is taken into account in the plans to strengthen existing territorial-production complexes and to establish new ones.

We will now examine the basic stages in territorial development and discuss the major factors involved in transforming specific sets of conditions that exercise a major influence on man's health.

The *first stage* is obtaining information on resources and other essential factors. Relatively small groups of geological explorers, transport and land surveyors, and builders spend time in the "wilds" of nature. They are exposed to the dangers of endemic infections and suffer from midges and ticks, heavy frosts, winds, rains, etc.

The *second stage* involves the development of certain areas of the territory, the creation of transportation communications and the initial work on constructing the infrastructure. This period is marked by a noticeable human intervention in the spontaneous development of geosystems. When territory develops into separate areas, the population continues to be subject to the pressure of the natural environment, and the size of the population is still restricted. At this time, there is a need for preventive treatment of endemic diseases.

During the *third stage* there is comprehensive and intensive development (industrial, agricultural, etc.) of a territory within the given territorial-production complex. This period is perhaps the most difficult and crucial, and may be characterized by a rapid population growth primarily through the influx of builders.

In the *fourth stage* there is highly intensive development--e.g., full-scale operation of industrial projects, completion of the building of urban agglomerations, establishment of highly mechanized agricultural enterprises. Territorial-production complexes acquire the final shape as envisaged by the regional planners.

In each of the development stages there are specific measures taken that are aimed at improving the territory. The positive effects of sanitation measures should override the negative effects of ecological factors. However, this cannot be achieved without medical-geographic forecasts.

A medical-geographic forecast (MGF) is made according to the following pattern. First, a tentative forecast (sometimes called a trend forecast) is made which makes it possible to foresee the development process even when it is uncontrollable and cannot be channeled in the desired direction. (This may be called the spontaneous development.) This helps to reveal uncomfortable or extreme situations that may arise in the process of territorial development or reconstruction. This type of forecast serves as a basis for making programs and organizational forecasts that are regarded by some authors as a single normative forecast. These interrelated forecasts, which define measures such as prophylactic and town planning measures, and those aimed at improving the external environment and protecting the biosphere, are designed to neutralize or weaken unfavorable sanitary-ecological phenomena.

Medical-geographic forecasts are made only for territories that are homogeneous in sanitary-ecological terms. For this reason the framing of a geographic forecast is always connected with scientific classification of territories, i.e., regionalization.

POPULATION ADAPTATION

In planning the economic development of sparsely populated areas, it is important to study how new inhabitants adapt. Population adaptation is a socio-biological process in the course of which the majority of those settling some territory adapt themselves to unusual conditions, thus enabling them to live normal healthy lives. Adaptation is achieved through physiological changes in the organism of the newcomer and through collective efforts toward creating an artificial external environment (clothing, housing, heating, production premises, transportation, etc.), as well as through the development and

accumulation of new behavioral habits. However, sufficiently effective adaptation to extreme environmental influences can be developed only over the course of several generations.

Inclement natural conditions strain all physiological mechanisms. Soviet geneticist V.P. Efroimson writes that in areas with extreme conditions man experiences a "superstress" which only the fittest of the newcomers can tolerate and only for short periods [6]. For several years healthy, physically fit people can withstand this stress, but then the protective mechanisms often fail. This is manifested in the general decline of health standards.

Reference is often made to the excellent adaptation of the native population to the severe natural conditions of the North. Indeed, the local people adapt very well to the local natural environment. But this adaptation has been going on over many generations.

Medical geographic charts provide valuable data to the town planners and adaptation experts. Several factors are taken into account in compiling these charts: a landscape characteristic of the territory which itself integrates many indicators, the type of economic activity of the indigenous population and old-time residents, and also the character of the present and future industrial development of the region. In view of the important and in some cases the decisive role of climate in determining living and health conditions, compilers of charts use more than ten parameters characterizing the climatic situation of each of the territorial-ecological systems. Within the territorial systems, the compilers note the preconditions for human diseases and, as far as possible, the nosological profile of the local population. Following the medical-geographic analysis of all factors of the anthropo-ecological environment an evaluation is made of the conditions for adapting new inhabitants. These conditions are arranged according to a five-point scale.

The following types of territory can be distinguished in Siberia.

Extremely uncomfortable arctic and subarctic plains and low plateaus. Industrial surveys and selective development of particularly valuable and unique natural resources are characteristic of this type of territory. Density of population is less than one person per km². The adaptation of young healthy people proceeds satisfactorily, but may be accompanied by complications. The adaptation of other groups of migrants is unsatisfactory.

Uncomfortable taiga areas in the north of Western Siberia and the taiga plains and low plateaus in the northern and central parts of Eastern Siberia. Selected areas develop, and there is in part extensive industrial development and the formation of large production complexes. These territories have a density

varying from less than one person per km² to more than ten people per km². The adaptation of young healthy people proceeds satisfactorily, but other groups of new inhabitants adapt poorly.

Semicomfortable taiga plains and low plateaus in the central and southern parts of Siberia. Industrial development, which eventually will be intensive, is characteristic of these territories as is the formation of large production complexes. Population density in some areas reaches 25 people per km². The adaptation of young healthy people proceeds well, and other groups of migrants adapt satisfactorily although for the latter there may be complications.

Altogether, there are 11 types of territories in the Asian part of the USSR that differ by adaptation conditions.

THE ACTIVITY OF POPULATION IN A CONCRETE GEOGRAPHIC SITUATION

The analysis of human activity in concrete situations and the description of the social and communal infrastructure are important for determining the medical-geographic features of the territory and the conditions to which the new inhabitants must adapt.

By comparing the working and recreational conditions of different groups and correlating these data with health indicators (e.g., birth and death rate, sick rate, physical development) it is possible to determine medical-geographic characteristics of development areas, and to forecast changes in the health standard of the population in the course of regional development.

WORKING, LEISURE AND HEALTH CONDITIONS OF THE POPULATION IN THE BITPC

Much of what has been discussed so far in this paper can be illustrated by the example of the study of the medical-geographic features of the BITPC by the Institute of Geography of Siberia and the Far East. The BITPC includes the Bratsk, the Nizhneilimsk, and the Ust-Ilinsk districts of the Irkutsk Region.

To draw a medical-geographic picture of the territory, we will compare the basic parameters of the sanitary-ecological situation in the BITPC with those of the central zone of our country as one of the areas of the origin of migrants.

The Mid-Angara area has long and cold winters with temperatures averaging below zero Centigrade for 190-195 days. In Bratsk, the heating period lasts for 246 days, where the mean temperature is 10.3 degrees below zero Centigrade. The total degree-days of heating in the Mid-Angara area is twice as high in Bratsk as in

Moscow. In Bratsk, cold spells with temperatures running 30 degrees below zero can last for 520 hours; in Irkutsk, which is to the south, they last 192 hours, and in, Chelyabinsk, only 40 hours. Thus, a migrant coming to work in the BITPC from the central zone of the country must adapt himself to more severe climatic conditions where winter lasts 1.5 months longer and is much colder.

Fog is a characteristic climatic feature of the Mid-Angara area, in particular, the valley of the Angara and its tributaries. In summer, fog is caused by small differences in air temperature coming to the valley at dawn from the watershed expanses and the warm air of the valley with a high moisture content. As a result of the Bratsk and the Ust-Ilimsk hydropower stations and the large water reservoirs, the part of the Angara River which is several kilometers below the dams will not be frozen in winter. The vast temperature difference between the open water surface and the cold foggy air create conditions for intensive precipitation of industrial waste discharges. The project for developing the Ust-Ilimsk industrial agglomeration took these climatic features into account.

The inclement climatic conditions in the Mid-Angara area affect the health of new inhabitants and cause pathological changes in the health conditions, especially of old people and those with chronic disorders. For several years the staff of the medical-geographic sector of the Institute of Geography of Siberia and the Far East in Bratsk surveyed new inhabitants of the region. Of the approximately 3000 people queried, about 10 percent had lived in the area for about one year, 35 percent for two or three years, 30 percent for four to five years, and 25 percent for five to ten years. The survey showed that during the first few months of their stay in the area, 87 percent complained of weakness, headaches, reduced ability to work, and quick onsets of fatigue. About 50 percent experienced dizziness, buzzing in the ears, nausea and vomiting. The most severe reaction was experienced by those coming in spring, autumn, and winter. Pathological reactions were more often recorded among women under 25 and over 40 years. People coming from Transcaucasia, the Baltic Republics, and the Ukraine proved to be more sensitive. Less clearly expressed reactions were observed among people from the north of the European and Asian parts of the USSR, the Trans-Baikal country, and Western Siberia. People who changed their place of residence for the first time reacted more sharply to the change in the geographic environment than those who have repeatedly changed their place of residence.

These data [7,8] agree with the conclusions drawn by researchers who studied these problems in other areas of the country. During the first years spent in the new climatic conditions there is a high incidence of diseases of meteo-tropic aetiology. People living in hostels and working in the open air are more subject to colds; this occurs mainly in winter and spring.

The soil types predominating in the Mid-Angara area are podzolic and soddy-podzolic characterized by a deficit of some biologically active trace elements such as iodine, fluorine, cobalt, and copper. The shortage of iodine in the soil and, consequently, in food causes an endemic goitre disease. The findings of the survey conducted in 1932 by V.G. Shipachyov showed that in villages along the Ilim River the goitre disease was diagnosed among 21 percent of the surveyed people. E.A. Pak's investigation [9] showed that the intensity of this endemic disease was sharply reduced owing to the use of iodized salt and non-local food products, and treatment. Among the new inhabitants the endemic goitre is less intensive than among the local population. It is manifested mainly during the first three years in the endemic area. Iodine prophylactic treatment is carried out to prevent the disease.

The waters of the Angara and its tributaries belong to the hydrocarbonate class, the calcium group, that have a low mineral content and a deficit of fluorine of which only 0.2-0.3 mg are contained in one liter of water. L.M. Yanovsky's investigations in 1975 showed that from 80 to 90 percent of school children aged 7-17 years suffer from dental caries. This agrees with the findings of other investigators concerning the connection between dental caries and the deficit of fluorine in drinking water [10].

At the early stages there is a health danger for builders as a result of endemic infections. This is why the study of these diseases in new development areas is given so much attention. A study of this type in the Irkutsk Region is to be found in the work of S.V. Ryashchenko [11]. According to the author, in the natural complexes of the BITPC there is a circulation of carrier agents of tularemia, tick-borne encephalitis, Q-fever, ornithosis, toxoplasmosis, and rabies. The filling of water reservoirs makes for the growth of hydrophytes in shallow zones and for the formation of breeding grounds for mosquitoes. Also, the colonization of the area by muskrats, aquatic and field rodents contributes to the formation of centers of tularemia and leptospirosis [12]. The health of people is undermined and their working capacity is reduced by massive attacks of blood-sucking double-winged insects (gnats, mosquitoes, biting midges, gadflies).

As a result of information on medical-geographic features of new territorial-production complexes and industrial agglomerations, it is possible to formulate scientifically based recommendations for improving working and leisure conditions. Long periods of inclement weather make it necessary to increase living space in flats, since people spend more time indoors here than in the central part of the USSR. The presence of such insects requires both individual and collective protection against attack.

The disease-provoking action of the deficit of iodine and fluorine is neutralized by enriching foodstuffs with products having a higher iodine content and also by adding fluorine to drinking water at water supply stations.

In the course of medical-geographic investigations much attention is given to selecting suitable sites for settlements, evaluating water supply sources, and to using domestic wastes.

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Integrative Elements of Regional Development†

W.A. Welsh

Provision for the well-being of the population must be a critical component of any regional development activity. Prokhorov's paper effectively demonstrates this point, and shows the interconnection among several elements of social and economic change.

Medical-geographic problems thus cannot be studied apart from other dimensions of regional development. Conversely, approaches to regional development that are not integrative and synthetic--which do not go beyond parallel and discrete investigations of the several dimensions of change--make little sense. Regional development should be *integrated* development.

An understanding of the problems of regional development must therefore be based on an integrative perspective. My principal concern with Prokhorov's paper is that the problems of integrating health planning with other aspects of the planning process are treated only implicitly. Regional development planning involves more than straightforward optimization along a series of parallel dimensions. Medical-geographic problem-solving, for example, involves more than forecasting the impact of a set of geosystem elements on the morbidity of a population with relatively predictable demographic parameters--although these problems are significant, as Prokhorov has shown.

Regional planning involves a series of complicated and overlapping policy choices. Possible inconsistencies between economic (production) goals and criteria for acceptable human living conditions must be identified. Priorities, both in terms of criteria for plan optimization and of sequence and timing, must be worked out. The availability of resources, financial and other, for carrying out development plans must be carefully examined. Contingency criteria to be applied in the event of mid-project reductions in available resources must be agreed upon. And, in general, the administrative means must be established whereby effective coordination of several aspects of development can be achieved. These are the integrative aspects of regional development, which are of central importance to each of the dimensions of planned change.

†Comment on B.B. Prokhorov, *Medical-Geographic Problems in the Formation of Territorial-Production Complexes in Siberia*, in this volume.

Figure 1 suggests a general perspective for examining these integrative elements for regional development. It might be worth reflecting briefly on some of the implications of such a perspective for handling the medical-geographic problems referred to in Prokhorov's paper. Provision for population well-being is dependent upon both *research* and *choice-taking*, which are beyond the competencies and responsibilities of experts in the medical-geographic and health planning fields.

The numbers in Figure 1 identify six critical junctures in the regional planning process that are of special significance to those interested in the basic character of human settlements (the "territorial community", in Prokhorov's terminology) in a regional project. Each involves policy choices of an integrative (i.e., overlapping n-dimensional) nature. How the relevant medical-geographic problems are handled depends on the nature of the policy choices made--and, in some cases, on when and how these choices are made.

MIGRATION PROCESSES

Prokhorov's paper suggests that it is possible to define the approximate population characteristics of a migratory "pool" from which migrants to areas, such as the Middle Angara Region, are likely to come. This pool differentiates itself from the general population in terms of age and sex, for example. We infer from Prokhorov's paper that suitability for adaptation to severe climatic conditions is a principal criterion for recruitment* into this pool. At the same time, there are other possible criteria according to which the migratory pool might be constituted, and certain policy choices are thereby implied. To what extent is the composition of migrants to any given development region induced or constrained by authorities? Are some who might wish to migrate denied this opportunity, for whatever reason? Are special incentives offered to others? To what extent are functional skills (specialized training, occupational experience) criteria for migration? If the demographic structure of the migratory pool is likely to result in temporary to medium-range social disequilibrium (e.g., because of the relatively small number of women, the absence of larger families, or the absence of older, more experienced workers), how are the social and economic costs of such disequilibrium projected, and what steps are to be taken to ameliorate these costs?

There is perhaps a more fundamental question concerning immigration into areas with severe climatic and other natural conditions. To what extent is massive settlement, based on substantial migration over many years, really necessary for the

*Recruitment is used here in its broadest sense, referring to the variety of factors that combine to make given persons more or less likely members of the migratory pool.

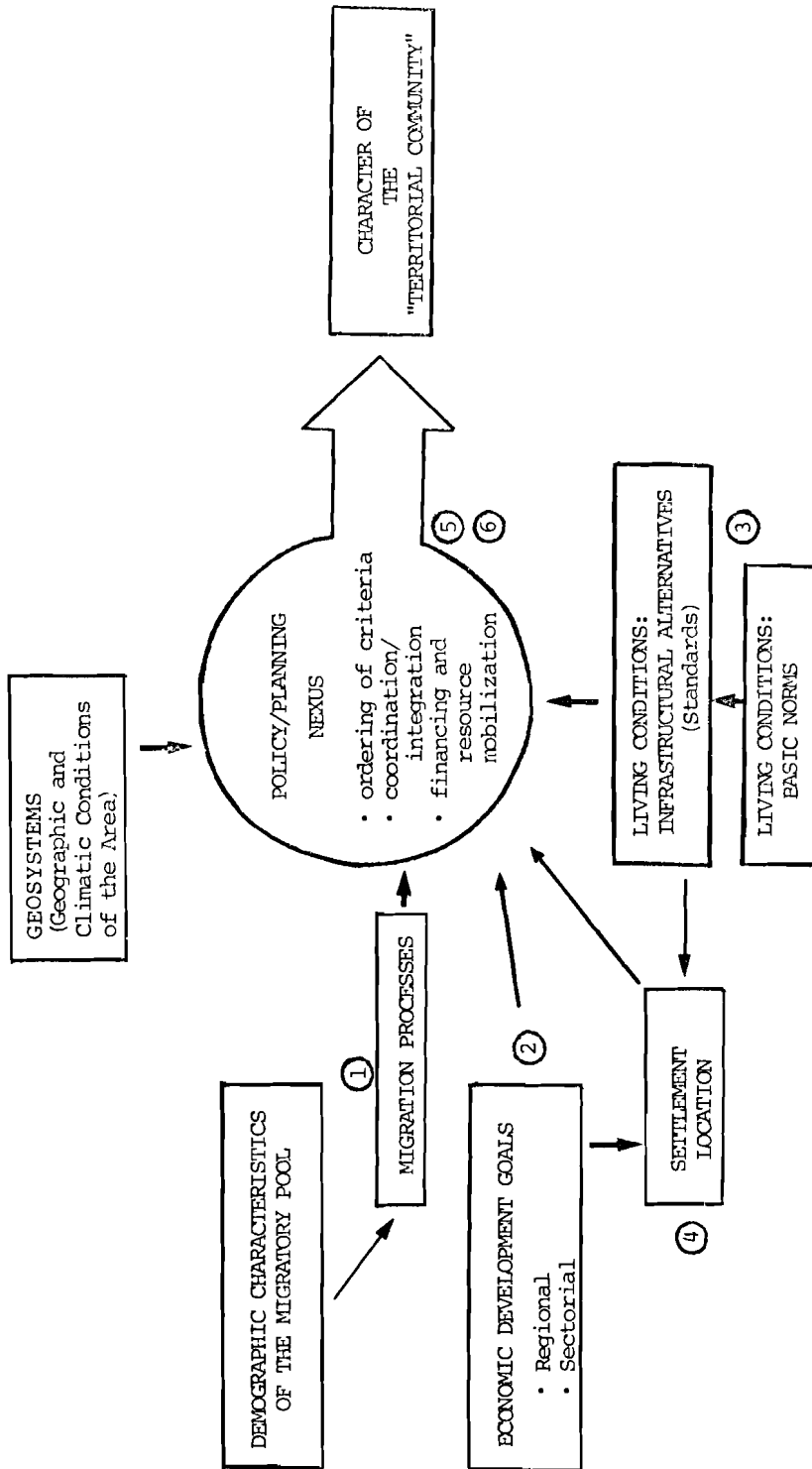


Figure 1. A perspective on integrated regional development and the nature of human settlements and services.

development of natural resources, energy capacities, or productive potential of the region? This question is raised in a forthcoming study by Slama [1]. He contrasts the policy for the settlement of central and northern regions of Siberia* with the Canadian Government's policy toward settlement of, and resource development in, the northern territory of that country. In the entire northwestern territory of Canada, with an area of approximately 3.5 million km², there are 40,000 inhabitants. The capital of this territory, Yellowknife, had in 1973 about 5,700 residents. By contrast, Murmansk has about 350,000 residents; there are five cities in northern Siberia that in 1974, had a combined population of 760,000. The extent to which this is composed of recent migrants can be seen when this figure is contrasted with the 1939 population of the same settlements, which totaled 187,000. To be sure, the territory of the USSR in question is larger than the northwest region of Canada, but nowhere near the population scale difference of nearly 20:1. Nor can the difference in settlement of the two northern regions be accounted for simply by differences in the two national populations, or by the extent of overcrowding of urban areas in more temperate climatic locations.

The point surely is not to adjudge one approach or the other to settlement of northern regions as appropriate. Rather, it is that policy choices among basic development strategies may in turn imply dramatically different patterns and magnitudes of migration into these areas. And this in turn will have great impact on the health care problems that must be addressed.

THE CHARACTER OF ECONOMIC DEVELOPMENT GOALS

Focusing economic development plans on a specific territorial unit does not necessarily mean that regional, as opposed to sectorial, considerations are being given priority. In nearly every society in which central economic and social planning has become well established, sectorial criteria have tended to predominate, and regional concerns have been given inadequate attention. The relative neglect of regional considerations is not difficult to explain in historical context (see for example [2,3]), but this fact does not diminish the implications of a strong emphasis on sectorial thinking. Broadly, a sectorial perspective asks how the economic potential of a given region can best be used to further efficient system-wide (national) economic and social goals. Because these national goals tend to be oriented toward the optimization of income or production functions,** such criteria

*It is worth noting that the principles of settlement policy for northern Siberia are by no means fully worked out or agreed upon. Slama [1] quotes G.A. Agranat, of the Institute of Geography of the Academy of Sciences of the USSR, to this effect.

**This comment is not intended to overlook the shift in emphasis in the USSR, for example, from gross quantity of production toward profitability of enterprises. The general point is that optimization criteria in national economic planning are nearly always income- or production-based. For example see [4].

dominate sectorial thinking. Sectorial approaches usually have not emphasized the maximization of social welfare or social service criteria. A genuinely regional perspective would be substantially more likely to give priority to the most effective integration of production and service activities within the regional system.

Similarly, sectorial perspective makes less likely the tailoring of national norms and standards in areas such as health care to special regional conditions. However, health care planning in the Soviet Union has long recognized the need for regional adjustments in national norms and standards [5] and this practice seems to have been followed in the case of the development of the Bratsk-Ilimsk Complex. However, regional adjustments in national plan criteria may lead to the institutionalization of regional inequalities in the nature of basic human services.

The extent to which a sectorial perspective, and/or an emphasis on production functions, might predominate in any regional development scheme has important implications for the planning of human settlements and the provision for population health and well-being. At base, the issues concern the setting of priorities among norms in different areas of human activity, as well as the extent to which strictly economic goals can be and are adjusted in the face of deteriorating conditions in the human and/or natural environments. Prokhorov mentions the "economic losses" that can be traced to deterioration of the health of the population. It is more than semantic distinction-drawing, I believe, to suggest that the criteria for measuring the impact of health deterioration might well be noneconomic in nature, as Prokhorov seems to suggest when he says that "all work is done for the good of man". It is important to ask, for example, whether economic production norms are adjusted in view of observed deficiencies in the physiological/health adaptation of the population to severe climatic and other geosystem conditions. The nature and severity of the challenges faced by health planners will vary substantially with the system of priorities established among the several criteria of economic and social development.

LIVING CONDITIONS: NORMS, STANDARDS, AND ALTERNATIVES

The "living conditions of the population" to which Prokhorov refers include a number of elements: medical facilities and personnel, health programs, housing, learning facilities, leisure-time facilities, transportation and roads, and the trade infrastructure. In each of these areas, both *norms* and *standards* exist in the USSR. Popov [5] contrasts norms and standards in health care, for example: norms are "scientifically established indices of environmental conditions and of the medical care required by the community or by various population groups, as well as of health facilities". Standards refer to the "resources required to meet the needs specified by the norms, i.e., indices relating to the public health facilities and the availability of medical care".

A critical, and erroneous, assumption made by many students of planning is that standards are "determined" by norms, i.e., that once norms have been determined, standards follow as trivial deductive conclusions. This is not the case. The determination of standards requires not only empirical research delineating the effectiveness/productivity of given health structures and personnel, but also policy choices concerning the most efficient way to use (inevitably limited) resources. In health care, for example, different systems seem to have chosen different combinations of emphases on (a) capital investment in health care facilities, (b) the training of health professionals, and (c) prophylactic health programs [6]. While such choices hopefully reflect substantial inputs from specialists in the area, questions of resource availability and efficiency may be determining considerations.

SETTLEMENT LOCATION

Regional planners are seldom able to specify the location of human settlements according to criteria that might maximize the quality of those settlements. Frequently, the practical choices are to develop one or more existing settlements, the locations of which reflect historical circumstances rather than contemporary conditions. Standards for amenities tend to take existing population agglomerations as given, and to specify how many facilities of a given type should be located there. This makes access to amenities substantially a function of the existing spatial distribution of population.

And even when wholly new settlements can be undertaken--as has been the case in the development of northern Siberian--there may be conflicts between criteria for settlement location that would maximize the productive capacity of the region, and criteria that would create the most hospitable living conditions for the population. Depending on the nature of the principal economic activity of the region, the location of major production units may be largely determined by natural factors, as with energy-producing facilities. Access to raw materials and energy sources is nearly always an important consideration in industrial location decisions.

These locational considerations for production units may be expected to coincide only infrequently with quality-of-life considerations for the population. Maximal environmental quality and productive efficiency can be difficult to achieve conjointly. Raw materials and recreation facilities may be found at locations distant from one another. Again, the point is not that such potential conflicts among criteria cannot be reasonably resolved; rather, we wish only to emphasize that policy decisions of a coordinating and integrative nature must be made, and these decisions will have a substantial impact on the planning of the location and the nature of human settlements and services, including health care.

THE NON-LEXICOGRAPHIC NATURE OF DEVELOPMENT PLANNING INTEGRATION

I have argued that the many planning decisions that must be made are highly interdependent, and that their interdependent (and overlapping) nature places great emphasis on coordinating and integrating functions. What is especially difficult about these integrative decisions is that the contending development criteria of relevance to each dimension of planned social and economic change are very difficult to order lexicographically. That is, no single valuational dimension is common to migration policy, production efficiency, settlement location, quality of human services, control of the natural environment, and efficiency of the plan implementation function. Alternative configurations of resource use are difficult to analyze systematically in the absence of a common overall criterion. The result is well-known: a single dimension of development--frequently production-oriented--is selected for optimization. The likely impact of such a perspective on the quality and comprehensiveness of human services has been sketched.

The possible role of, for example, health care norms and standards in what Prokhorov calls a megasystem model can be outlined more specifically. We can imagine health care indices appearing as (a) endogenous variables in the model, the values of which depend on the form of relationships among variables in the model, and on the specific criterion variable(s) being optimized; (b) exogenous parameters which impose constraints on the values of variables in the model; and (c) on endogenous criterion variables to be maximized.

It is reasonable to suggest that possibility (c) represents the most significant role that could be accorded health care norms and standards, whereas possibility (a) probably represents the least important role. Which of these roles is reserved for health care indices in a regional development model will be determined by a series of integrative decisions which, assuming finite resource availability, are not noncontroversial.

THE FINANCING OF REGIONAL DEVELOPMENT

A concentrated development program, regional or other, requires significant resource commitment, especially finances. There is a tendency in the literature on regional development to discuss development desiderata in the abstract, as if the availability of resources were not problematic. This clearly is an unrealistic posture; there is no society in which all attractive possibilities for resource use can be simultaneously served. Resources are limited. The commitment of funds and manpower to one set of activities implies tradeoffs; some things are not done because others are.

Some of the implications of resource scarcity are straightforward: scarcity implies choice, not only between projects, but

also within projects and between segments of the activity. It may not be possible simultaneously to develop extractive raw material capacity and to provide optimal health programs and facilities, for example. Such decisions are integrative/coordinating ones, to be made at what Prokhorov calls the megasystem level. These have obvious implications for development activity within each dimension of regional planning. Some things will be postponed; others will be canceled, or never seriously considered.

There are other aspects of these issues of financing development which may be less obvious, but which are equally as important. They have to do with the relations between central and local-regional government units, and with the resulting long-run vitality of the latter. For our purposes, two points should be stressed: (a) concentrated regional economic development programs tend to be centrally-initiated and initially financed from the center, and are only gradually sustained by increasing resource inputs from the affected region itself; and (b) human services, such as health care, tend to be the responsibility of subnational units of government in most societies, and must be sustained from the outset by those units. The results frequently are that social services lag behind the growth of economic production, and regional inequalities in the availability of public goods and services are maintained and even accentuated.

In the USSR, all of the measures directly serving the needs of broad sections of the population are carried out by local budgets. Administrative units at the republic level and below have sole responsibility for education, for housing and municipal services, for cultural services, and for all health and social maintenance funds [7]. Subnational units of government account for well over one half of total public expenditures, and a higher proportion of expenditures on basic human services.

For our purposes, what is critical is that human services that are locally and regionally financed in the USSR continue to show substantially more marked interregional variation than do measures of overall economic growth [8]. System-wide trends toward equalization in gross economic development are reflected only very marginally in social services. This is the case despite the fact that norms for economic production are tailored more specifically to interregional differences than are, for example, norms in education or health care. In the simplest terms, regional development programs carry with them the potential to perpetuate or even increase interregional disparities in the availability and quality of basic human services. The principal implication is that regional development projects should be imbedded within overall national development plans which are sensitive to the need to reduce interregional inequalities, and give commensurate attention to those elements of human living conditions that are, in the long run, critical to societal development.

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Summary Report on the Technical Session
On Demographic and Medical Problems

A. Kiselev

The demographic and medical processes in the Bratsk-Ilimsk Region are of great interest from a theoretical point of view. The population of this previously uninhabited region has increased almost ten times over the last twenty years. Actually, we can regard the demographic and medical processes taking place here as a pure experiment because elsewhere they usually extend for many years. Thus we have a model situation which could be reproduced only by means of simulation models.

From the applied systems point of view, the experience gained in developing the BITPC is of interest not only to the Soviet Union and other developed countries, but also to those developing countries that are faced with problems of creating industrial complexes.

From the methodological point of view, the discussion of methods of planning and predicting the development of demographic and medical processes yielded valuable information that is applicable to other projects of this type.

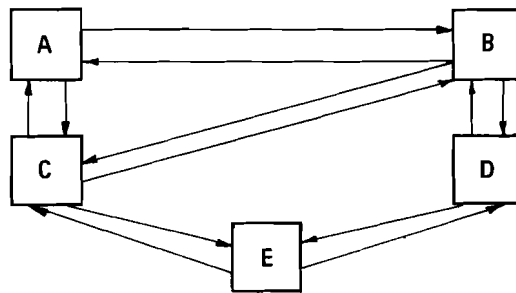
The presentations and discussions of demographic and medical problems encountered in the development of the BITPC have shown that these problems are closely connected to such factors as economy, geography, ecology, climate, and administration. The use of systems analysis and complex dynamic simulation models are effective in determining the best strategies for the development of a region. A major criterion is careful planning that takes into account social as well as medical factors since the provision of adequate health care is essential to the well-being of the population.

MODELING REGIONAL DEVELOPMENT

Modeling of Territorial-Production Systems:
Case Study of the Angara-Yenisei Region

A.G. Granberg and M.K. Bandman

Research on building models of economic development of units of different sizes is being conducted at the USSR Institute of Economics and Industrial Management, in Novosibirsk within the framework of constructing a general system of models of optimal national economic planning. The system reflects the interaction of two hierarchical structures of the economy--*productive* and *spatial*--and includes five blocks (subsystems) corresponding to the three levels of the national economy (Figure 1).



- A Point national economy models;
- B Spatial territorial-national economy models;
- C Models of sectors and multisectoral complexes;
- D Regional models;
- E Models of self-accounting production units.

Figure 1. System of models.

The description of the system is given in [1,2]. This paper examines the territorial aspects of the general system of models. Joint elaboration of the models allows one to link the development plans of individual territorial units with those of the national economy. The feasibility of this method of organizing territorial planning processes is being studied with special reference to the Angara-Yenisei Region and its main territorial-production complexes, including the BITPC.

TERRITORIAL MODELS OF THE NATIONAL ECONOMY

Development programs for a large region such as the Angara-Yenisei are worked out on the basis of long-term national plans and forecasts that indicate important regional problems and possible solutions. Therefore, territorial-national economy models are the starting point for simulating territorial-production systems.

A model that incorporates the conditions of development for all industries and regions of the country is the main type of territorial-national economy model. The earliest versions of such models were developed by the American scientists Leontief [3], Isard [4], and Moses [5]. These models represented a generalization of the input-output model, and were reduced to a system of algebraic equations with a unique solution. (This was achieved by determining the most important parameter of the territorial proportions which is either the structure of territorial distribution of production or the structure of interregional links.)

The creation of optimization intersectorial interregional models (OIIM) in the late 1950s and early 1960s was the next important stage in the modeling of territorial systems. In the USA, this was done by Stevens, Moses, and Isard, and in the Soviet Union by Aganbegyan, and Kossov.

Studies of the OIIM have been conducted since 1962 at the USSR Institute of Economics and Industrial Management. Several model versions have been designed. Our approach may be characterized as follows: an OIIM is constructed as an upper-level unit of the general system of models--it is connected through its inputs and outputs with point models, and with sectorial and regional models of the national economy; and an interregional model may function as a self-contained specialized national economic model.

The model that has been used for optimization calculations of the main territorial proportions of the Soviet economy now includes the following: regional balances of capital investments for the entire planned period; regional balances of production and distribution of output for the previous year; regional balances of transport operations; regional manpower balances; restrictions for certain variables (e.g., production units, interregional deliveries), which are introduced to determine limited natural resources, available productive capacities, advisability of lowering outputs, etc.; and an optimality criterion. Thus it is possible to identify an alternative to developing and locating production facilities (e.g., outputs of production sectors, capital investments, transportation costs) that ensures maximal funds of the nation's non-productive consumption for the given sectorial and territorial pattern. The description of the model is given in Appendix 1.

The OIIM modifications are distinguished by two main features: production and transportation factors are combined in the model; and regional development dynamics are taken into account in the model. With respect to the former, models may be classified as follows: interregional deliveries are incorporated in regional balances; only the net interregional exchange balance is incorporated in regional balances; and transportable product balances are given for the country as a whole, with regions being specified as production units.

Although models of the first type are regarded as basic, they do not allow one to substantially classify industries and regions. Other variants can be used when the problem is divided into separate production and transportation subproblems that can be solved by iteration of partial solutions. According to regional development dynamics, the developed and tested models may be differentiated in the following manner.

The main indices (production, consumption, interregional links) are calculated for the final year of the planned period, with restraints on capital investments for the whole planned period and assumptions regarding the use of the fund of capital investments in the final planned year.

The main indices are also calculated for the final year under given laws of growth of capital investments, while the growth parameters and absolute figures for capital investments by regions are determined in the process of optimization.

For a long-term period, the main indices of the final years of the five-year plan periods are calculated under the given laws of growth of capital investments by regions within these five-year periods.

In the first two approaches, attention is focused on the proportions of the final year of a planned period (10 to 15 years). After obtaining the solution for the final year, the dynamics of regional development can be "reconstructed" by solving a series of static problems for each year. The model of the third type combines features of fully dynamic models (in a large time scale) with those of simplified dynamic models under the given laws of growth of capital investments (in a more detailed time scale). It is also possible to reconstruct the annual dynamics of the main indices.

An important criterion incorporated in the main versions of the interregional intersectorial model is as follows: maximize the nation's consumption level with the calculated ratios of regional consumption levels and the rules for determining intra-regional consumption patterns.

The optimality criterion used is a single parameter one. The modifications of the model are related first to the definition of "regional consumption level" and, secondly, to the use of different laws for determining intraregional consumption pattern. For models where population and manpower in the planned period are determined for the regions (with due account of population growth forecast and expected migration), the regional consumption level characterizes aggregate consumption of the entire population of a region. For more complicated models with varying population numbers, this same notion characterizes per capita consumption. The consumption levels of services and goods, or of groups of goods, are determined as functions of the regional consumption level.

In interregional models the correlation of the consumption levels of different regions becomes a tool of the economic policy directed at leveling out regional living standards. Given the rules for forming intraregional consumption patterns, optimization by means of the above criterion gives a variant of the development and territorial distribution of productive forces with the following property: it is impossible to increase the consumption level in any one region without decreasing it in at least one other region.

Until recently, the OIIM calculations have been conducted for periods of 10 to 15 years in 16 sectors of material production and 10 to 11 economic zones of the Soviet Union (including West Siberia, East Siberia, and the Far East). The results of the first stage of the calculations are given in [6]. Calculations for the period 1976 to 1990 are being made. Interindustry balances (inout-output tables) built for all the Union Republics and economic regions of the Russian Federation serve as basic data.

Some of the results of optimization calculations for East Siberia are given below.

Different calculation variants show that the average annual rates of increment of the gross industrial production of East Siberia steadily surpass the mean national rates by 1.2 to 1.3 times. (According to the 1971 to 1975 Plan, the gross industrial output of East Siberia should increase by 68 percent, whereas the national figure will show an increase of only 47 percent.) Differences in the growth rates of various industries are characteristic of the optimal variants. Given more uniform industrial growth rates, it would be impossible (owing to labor scarcity) to adequately develop the industries of national specialization. Compared with other regions, East Siberia has the highest manpower scarcity.

The distinctive features of the development of East Siberia are fully applicable to the Angara-Yenisei Region, where a good part of natural resources and development centers of national specialization industries are concentrated.

The sectorial structure and external ties of the Region are flexible in relation to the growth rates and proportions of the Soviet national economy. This may be explained by the fact that the Region already meets a large part of the national need for nonferrous metals, and, in the near future, will become the country's most important power producer. Also, the Region has a severe manpower shortage. As a result, fluctuations of estimates of the national need for fuel, power, nonferrous metals, and timber products require considerable changes in the output of the corresponding industries in the Angara-Yenisei Region while, because of manpower shortage, the output of other sectors can change, as a rule, only in the opposite direction. On the other hand, impediments to the development of specialized industries in the Region will reduce the national development rates.

An analysis of calculations based on OIIMs shows that the development of the Angara-Yenisei Region and that of the country as a whole are closely related. From this viewpoint, the Region is important, and it is therefore difficult to consider it in isolation from the system of national economy. When studying the development prospects of the Region, we must not limit ourselves to the use of the main OIIM version. In the existing OIIM, a region is treated as a point (a production and consumption center), production sectors are integrated, and many regional resources and the intraregional distribution of the productive forces are ignored.

An approach to modeling the Angara-Yenisei Region in the system of national economy is to construct an OIIM with a more detailed block for the Region. Such an expanded model involves no special changes to the Region's block structure. Apart from the conditions that are part of the main OIIM version and which relate to a region considered as a separate unit, the modified model includes the rules of aggregating external links of the Region--i.e., amounts of exports and imports.

TERRITORIAL MODELS OF AN ECONOMIC REGION

The use of mathematical models for developing the productive forces of a region and its parts is done in two interrelated stages. In the first stage, the *production pattern* is examined, and in the second, the *spatial pattern* of the economy of a large economic region and its parts is analyzed (Figure 2).

The task of the first stage is to determine the best alternative production pattern, distribution, and use of multipurpose resources of a region. This involves developing the productive and social infrastructure, and ensuring that the region fulfils its quota of deliveries of specialized products, meets living standards requirements, and observes the introduced restraints. Data for the first stage may be found in the solutions to national problems, using intersectorial, interregional, and sectorial models, i.e., data on the distribution of the productive forces by

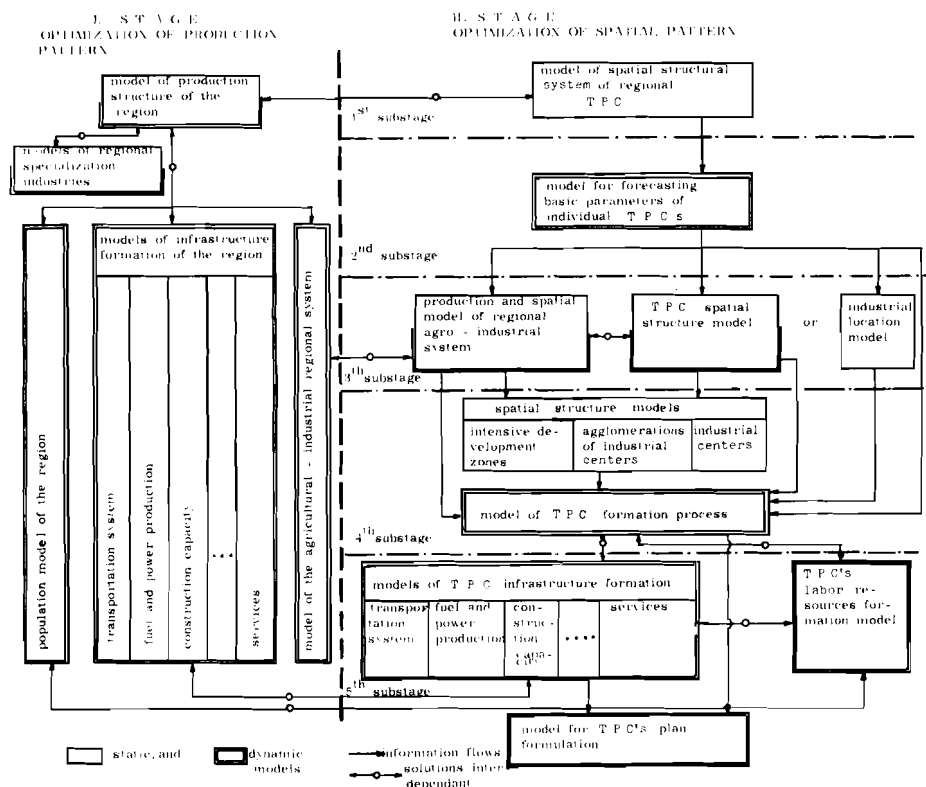


Figure 2. Scheme of optimization of economic pattern of the Angara-Yenesei Region.

region. The production pattern of the economy of a region is studied in two substages. First, the region's economy is analyzed as a whole, followed by an analysis of individual intraregional intersectorial problems, which may vary for different regions. The problems of the first stage are solved through the use of intersectorial models, and involve developing a series of models that give due consideration to the characteristics of each intraregional problem.

The task of the second stage is to determine the spatial characteristics of regional territorial-production complexes (TPC). This involves defining their place in the inter- and intraregional labor division, identifying the best alternative strategies for using the resources and the most efficient spatial organization of all elements of the economy. Models of TPC formation optimization may be used for these purposes.

This approach is based on the principle of step-wise, element-by-element analysis of the components of a region's economy,

starting with problems of forming large-scale TPCs in an economic region, and gradually turning to problems of developing and locating individual elements of the economy and territorial subdivisions of each of the TPCs (Figure 3). Production, infrastructure, resources, and forms of the territorial organization of production are analyzed at all substages (Figure 4). However, the analysis at each stage differs in scope.

Variants of location of production sectors	First stage	Location of regional specialization units and elements of interregional and regional infrastructure. Determination of layout of TPC and of isolated large industrial centers and their specialization.
Conditions for developing local resources	Second stage	Specification of pattern, analysis of time variants of formation. Determination of main parameters of each TPC.
	Third stage	Location of all elements of the economy and population within each TPC. Determination of the layout of intracomplex industrial centers and zones of intensive development of agriculture and their specialization.
Level of development and spatial distribution of production in basic year	Fourth stage	Location of all elements of the economy and population by subunits of intracomplex PC. Determining the functional zoning layout of the territory of intracomplex PC and the population settling.
	Fifth stage	Determination of the variant of formation of TPCs as a whole. Determination of the variant of formation of individual elements of the TPC economy. Determination of the variant of TPC creation plan.

Figure 3. Sequence and content of optimization stages of the spatial economic pattern of a region.

GENERAL APPROACH - TASKS AND METHODS

Three main types of objects are set out at each substage for the spatial pattern optimization of a region and its components: territorial taxonomic units (areas, sites, plots), functional elements of an economy (production, infrastructure,

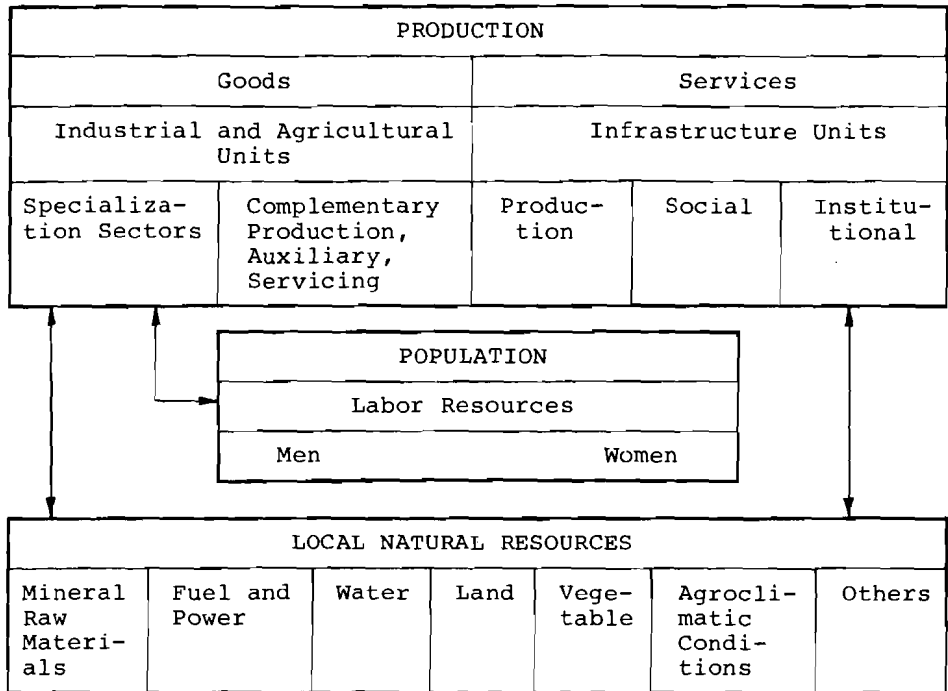


Figure 4. Main elements of a territorial production complex.

resources), and production-transportation links. This classification was necessary in order to take into account the specific features of each object and its place in the formation of the region's economy. Joint consideration of all elements of the economy is one aspect of the proposed approach to optimizing the economic spatial pattern of a region, a TPC, or an industrial center.

A possible set of territorial taxonomic units and their characteristics, a set of resources, and the variants of their use are determined prior to solving the problem. In the process of spatial pattern optimization, areas (sites, plots) are selected for the economic elements, the ways of using resources are determined, and expenditures are specified.

The composition and units of specialized industries, the production scopes, and the directions of the main production links are determined by solving higher level problems. The process of spatial pattern optimization also serves to define the general layout of the units, and the provision of local resources and infrastructural services, as well as to specify production links and certain technical and economic indices.

The composition and the development scope of auxiliary and servicing production sectors are not assigned from a higher level. These indices and the overall plan for location and production links are determined by finding out the amount of corresponding goods and services needed by all elements of the economy and by the population of the territory being studied, taking into account local resources, the specific features of raw materials, and semi-finished or finished products. Expenditures are also specified.

It is impossible to solve the problems of the formation of the productive infrastructure (e.g., transport, power and fuel production, water supply), and the social infrastructure (e.g., cultural and educational institutions, consumer services) without analyzing the economy of the territory as a whole. For those individual units of the infrastructure whose importance extends beyond the territory being studied, a special assignment is introduced to meet the needs of the territorial units of a higher level. The requirements for the provision of services and for their growth as well as the location of service units and their links are determined, and the expenditures are specified for all the elements of the infrastructure.

The population is regarded, on the one hand, as the producer of goods and, on the other, as a major consumer of resources, goods, and services. The factors to be determined are the manpower requirements of the TPC and also how manpower can be supplied to all parts of the TPC economy. Expenditures for attracting and retaining manpower are defined, with due account of expected living conditions and migration processes. The effect of the existing settlement pattern on the location of all economic elements is analyzed.

Solutions to these problems will provide a key as to how to distribute the manpower among the sectors, determine the basic settlement pattern and population size of the main settlements, and specify the outlays for attracting and settling the newcomers.

After analyzing the natural resources their sources are chosen along with the scope of development and the development variants. Also specified are their links with consumers and expenditures.

Climatic, biotic, and recreation resources, the condition of the atmosphere and certain other natural conditions are distinguished as a separate group. Protection and reproduction of resources are also considered.

The composition, scope, directions, and ways of implementing internal production and transportation links (excluding technological ones) are defined, while external links, as a rule, are assigned and corrected only as a result of the solution to the problem.

The problems of all substages are solved so as not to interfere with the fulfillment of the production goals of specialized industries and with the development of infrastructural units, which are significant not only for the territory under study. One other requisite is to satisfy constraints on scarce resources, taking into consideration the special features of the functional units and parts of the territory being studied.

The main criterion for determining whether a variant of the spatial pattern is optimal is a minimal aggregate outlay for the formation and functioning of the economy of the territory being studied. This will help determine the effects of location, concentration, and organization of the economy.

The solution to this group of problems gives the best possible variant of the use of resources, territorial distribution of the industrial and agricultural units, location and rates of growth of infrastructural elements, layouts of internal and external production-transportation links, settlement pattern, location of main intraregional complexes, their specialization, scale of development, and links. In addition, it is possible to determine shadow prices which can be used to analyze various situations when drawing up Master Plans and other planning documents.

The data sources for solving problems at all substages include solutions to higher-level tasks, studies carried out by sectorial and territorial R&D institutions and other scientific institutions, documents by local administrative bodies, and normative materials (Figure 3).

In the second stage of optimization of the regional economic pattern, a group of models of TPC formation optimization is suggested. We believe that the use of these models ensures solutions to the complex problems of determining the territorial pattern of a region's economy (Figure 2). Territorial-production regional mesomodels* designed for this purpose make up the core of the group of models of TPC formation--models of substages I, III, IV in Figure 2). These are models of spatial economy that analyze all the elements of the economy, and the resources and forms of the territorial-production organization within the boundaries of the region being studied.

The territorial-production regional models of TPC spatial pattern optimization are constructed of blocks. Each of the blocks characterizes the conditions of formation and functioning of individual elements of the economy, the use of individual resources, or the participation of the given TPC in the territorial labor division. The number of individual blocks and their contents depend on the problem and the TPC rank. Thus, for instance, five blocks form the basis of spatial pattern models of the TPC

*The term mesomodels refers to models of entities located lower than national level (macromodels) and higher than basic units (micromodels).

system: (1) production, (2) infrastructure, (3) labor resources, (4) local resources, (5) external links, (6) restraints, and (7) objective function (Figure 5). Each of these blocks, in turn, is subdivided. Set apart in the production block are the

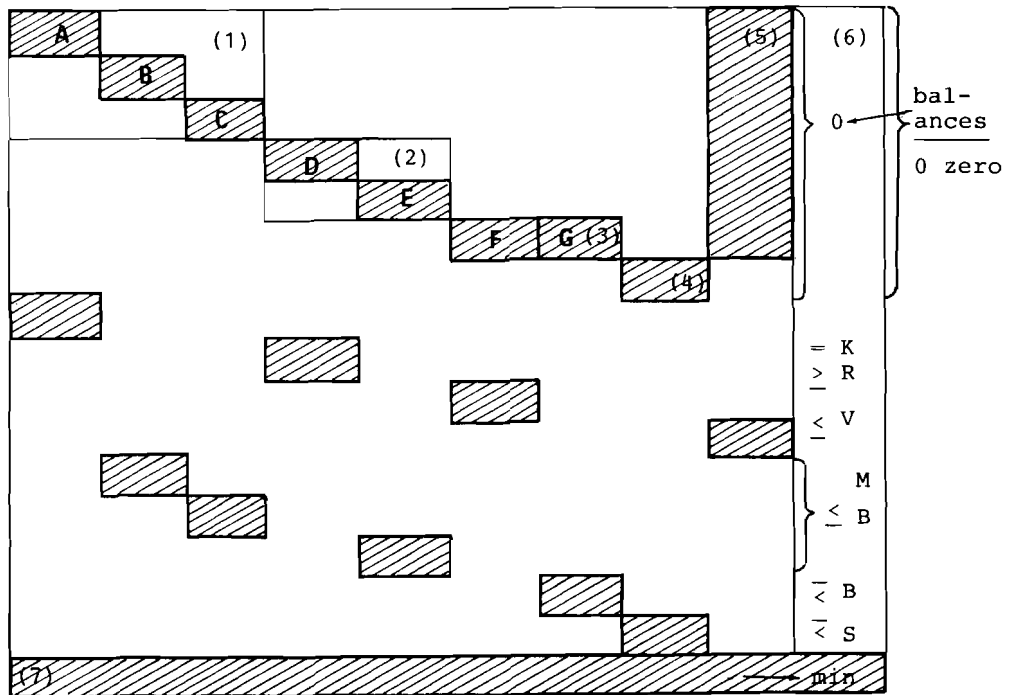


Figure 5. Block-diagram of a spatial pattern model of the region's TPC system.

following sub-blocks: (A) specialized sectors, (B) complementary industries and (C) service industries; in the infrastructure block there are sub-blocks of the elements of productive and social infrastructures, which are (D) important beyond the boundaries of the TPC, or (E) important only within these boundaries; in the manpower block, for example, there are sub-blocks of (F) local resources, and of (G) "imported" resources. Distinguished within the sub-blocks are production units, elements of the infrastructure, resources, and external ties.

The objects of simulating in regional mesomodels for each level of the TPC are the elements of the specialized sectors of a TPC and the complementary industries, and the productive and social infrastructures and territorial units. The methods used

reflect the conditions of the formation and functioning of each object of simulation. The specific interrelation of each of these objects with the entire system of the TPC complex can be quantitatively expressed in matrix coefficients. The criterion used is reduced outlays for the construction and functioning of the TPC being studied, provided the constraints are satisfied.

Regional mesomodels of the spatial pattern optimization of a TPC at any level usually include the following. (Note that there may be problem situations where some of the above balance equations do not apply.)

- Balance between the output and production needs of specialized and complementary industries;
- Balance between growth rates and infrastructural services of each complex, with due recognition of the needs of higher level TPCs;
- Balance between the need for and the supply of local resources by main internal territorial units for each TPC;
- Balance between the need for and the supply of manpower, taking into account the possibility of attracting manpower from outside the area;
- Balance between the need for and the supply of mobile resources, taking into account the possibility of importing them from outside;
- Constraints from above factors: assignments for outputs of specialized sectors (K) and for the development of those infrastructural elements (P), whose significance goes beyond the TPC being studied;
- Additional constraints representing possible limits to the use of local resources (S) and manpower resources (R), capacities of certain enterprises (M), and limits on scarce resources (V and L);
- The objective function of the TPC--the main elements of which are outlays connected with the creation and functioning of production units and infrastructural elements, with implementation of external ties, development of local resources, attraction and settling of population, with due account of the planned living conditions (Appendix 2).

In the second stage of the research, three types of problems are to be solved which differ in content and require special economic-mathematical models and special principles for their construction. The following types of problems can be distinguished:

- Determination of economic spatial pattern variant of each TPC;
- Analysis of the formation pattern of individual TPCs;
- Determination of the formation variant of separate infrastructural elements and the organizational plan for each TPC.

The problems of the first type can be formulated as follows: to determine the variant of resource utilization, and the location of productive and infrastructural elements of the TPC, taking into account that the TPC must perform its function in the territorial division of labor and that expenditures for organization and functioning are minimized. A series of models corresponding to a definite TPC level have been suggested for solving this type of problem: for a region, a model of the spatial pattern of the regional TPC system would be appropriate; for an individual TPC, a model of the spatial TPC pattern and a model of the regional agrarian-industrial complex, or a model of the territorial distribution of industries is suggested; for a part of the TPC, models of the economic spatial pattern of an intensive development zone, of an individual industrial center or an agglomeration of industrial centers would be appropriate (Figure 2). All of these models belong to the group of territorial-production regional mesomodels whose prototype has been developed for this purpose. In each of the models, production, infrastructure, and the resources of the TPC concerned are examined simultaneously.

Each of these models was used at the Institute of Economics and Industrial Management to solve complex problems [7]. Some of the solutions were applied in developing regional planning of the Chulym area, the Irkutsk Province, and the Krasnoyarsk Territory, and in collecting data on East Siberia as a whole and on the Krasnoyarsk Territory.

The problem of the second type can be stated as follows: check, for every individual TPC, the deadlines and rates of development of specialized industry objects, the growth rates of complementary production units and infrastructural elements, and the use of resources, provided the outlays for the creation of the TPC in question are minimized.

Dynamic optimization models corresponding in each particular case to the aims of the research substage are a possible solution to this problem: for the second substage, a forecasting model of TPC main parameters; and for the fifth substage, a model of the processes of TPC formation. These describe possible formation methods of development variants of complementary production units and all elements of infrastructure and resources used. Joint and interrelated consideration of all production units and all infrastructural elements is a great advantage of these models, since this allows one to present in full the process of formation of

the TPC being studied. This is also a distinction by which these models differ from the models intended for the solution of the third type of problems.

A series of experimental problems have been solved with the help of these models based on data on the Sayany and Mid-Ob TPCs [8].

Models for solving the third type of problems are used to specify the variant of location, links, growth rates and pattern of each of the infrastructure branches of the TPC concerned, provided the reduced outlays for the creation and operation of the economy of the TPC and also of the branch are minimized. The basic difference between the second and third type of problem lies in analyzing separately the formation of each individual branch of the infrastructure (transportation system, construction capacity, fuel and power system, etc.). The study of the interrelations of each of the branches of the infrastructure and the economy as a whole allows one to obtain a detailed outline of the formation of this infrastructure branch and also to adjust the related expenditure. The solution for each of the infrastructure branches of a TPC is reconciled with the results obtained by solving the problems of forming an appropriate infrastructure branch of a higher-level TPC or the whole region.

Practical calculations of this type of problem were conducted with a view to optimizing the creation of the building capacity of individual TPCs--e.g., the Bratsk and the Boguchany industrial centers of the Angara-Yenisei Region. Various approaches and models for solving the third type of problems are proposed in [9]. An analysis of the results of these experimental calculations indicates that network linear dynamic models can be used for this purpose.

Thus, many of the models discussed have been experimentally tested by solving a series of problems for the TPCs of the Angara-Yenisei Region.

Aggregate types of production and some individual production units that are promising for the Angara-Yenisei Region were identified; specialized sectors' growth rates and the pattern of inter-regional exchanges were determined; areas or sites suitable for development were selected; and variants of possible locations of the production units being considered were mapped out. Power production, iron and steel, and nonferrous metals, chemistry and machine-building were considered as specialized industries for this region. The number of different types of units was as follows: in power production, two types of units were considered which differed in terms of technological patterns and locational requirements; in iron and steel there were two; in nonferrous metals there were nine; in the chemical industry and the machine building industry there were five. The new units of the timber industry and of other sectors whose location had been determined, as well as all operating units of all sectors were considered

predetermined in allocating resources. The composition of specialized sectors, complementary industries, and the infrastructure of intraregional TPCs were also determined. Territorial taxonomic units were disaggregated at each substage of the solution.

Many studies have been devoted to the long-range development of the productive forces in Siberia, and we therefore did not expect our calculations to yield any unexpected, new results. The solution to a series of experimental and practical problems conducted at the Institute of Economics and Industrial Management confirmed many of the initial propositions and hypotheses made about the development of the production forces of the Angara-Yenisei Region. These findings showed that specialization of certain territories mapped out as a result of studies conducted in the 1930s to 1950s was essentially maintained.

Our calculations allowed us to obtain a more precise outline of various territorial-productive combinations and to specify their ties and economic pattern. The role of individual factors and conditions in the development of the economy and its spatial organization has become more evident. We are more aware of the shortcomings in solving certain problems, and that some solutions are made at different levels and many indices reflecting actual conditions of the development of certain areas are lacking. The solution to each problem yields new data that often substantiate or reject an accepted point of view.

Appendix 1

BASIC VARIANT OF INTERREGIONAL INTERSECTORAL MODEL WITH
OPTIMIZED PARAMETERS OF THE GROWTH OF CAPITAL INVESTMENT

The model embraces n branches, not counting transportation ($i, j = 1, \dots, n$), and m regions ($r, s = 1, \dots, m$).

Unknown Variables

- \hat{x}_i^r : production output of the i -th sector in the r -th region obtained in the previous year with the use of production capacities operating at the beginning of the planned period. (Numbers beginning with the $(k+1)$ -th are ascribed to the sector, creating elements of investment.);
- \bar{x}_i^r : production output increment of the i -th sector in the r -th region due to investments for capacity expansion;
- x_T^r : production volume of transportation in region r ;
- x_i^{rs} : delivery volume of products of i -th sector from r -th region to adjacent regions. (Only links between adjacent regions are directly taken into account.);
- u_i^{tr} : expenditure of production investments of i -th type in the r -th region in the year t . (Planned period comprises T years.);
- z : total volume of nonproductive consumption.

Parameters

- N_i^r : production output of branch i in region r , which can be obtained in the last year of the planned period with the use of productive capacities operating at the beginning of the planned period;
- q_i^r : fixed part of final use of products of sector i in region r ;
- L^r : labor limit for the production sphere in region r ;

- \bar{d}_j^r : maximum admissible output increment of sector j in region r ;
- \underline{d}_j^r : minimum output increment of sector j in region r ;
- δ_{ij} : element of the unit matrix;
- \bar{a}_{ij}^r : product expenditures of sector i per product unit of sector j in region r with the capacities operating at the beginning of the planned period (old capacities);
- a_{ij}^r : product expenditures of sector i per product unit of branch j with the capacities brought into operation during the planned period (new capacities);
- h_{ij}^r : expenditures of investments of sector i per product unit of sector j in region r , obtained with new capacities;
- \bar{l}_j^r : labor expenditures on production per product unit of sector j in region r obtained with old capacities;
- l_j^r : labor expenditures per product unit of sector j in region r obtained with new capacities;
- $a_{j\tau}^r$: product expenditures of sector j per unit of transportation in region r ;
- l_τ^r : labor expenditures per unit of transportation in region r ;
- $a_{\tau j}^{rr}$: transportation expenditures in intraregional haulage per product unit of sector j in region r ;
- $a_{\tau j}^{rs}$: transportation expenditures on haulage of a unit of produce of branch j from region r to region s ;
- α_i^r : share of nonproductive consumption fund of the country that falls on the consumption of products of sector i in region r ($\sum_{ir} \alpha_i^r = 1$).

All unknown parameters except u_i^{tr} and h_{ij}^r , are relating to the previous year of the planned period. For simplification of notation, the variables and parameters relating to export and import of products and to power transmission are not given.

Conditions:

$$\sum_j h_{ij}^r \bar{x}_j^r - \sum_{t=1} u_i^{tr} \leq 0 \quad (i = k+1, \dots, n; r = 1, \dots, m) \quad (1)$$

$$\begin{aligned} & \sum_j (\delta_{ij} - \dot{a}_{ij}^r) \dot{x}_j^r + \sum_j (\alpha_{ij} - a_{ij}^r) \bar{x}_j^r - a_{it}^r x_t^r - a_i^r z \\ & - \sum_{s \neq r} x_i^{rs} + \sum_{s \neq r} x_i^{sr} \geq q_i^r \quad (i = 1, \dots, n; r = 1, \dots, m) ; \end{aligned} \quad (2)$$

$$\begin{aligned} & - \sum_j a_{\tau j}^{rr} x_j^r - \sum_j a_{\tau j}^{rr-r} x_j^r + x_\tau^r - \sum_{s \neq r, j} (a_{\tau j}^{rs} - a_{\tau j}^{rr}) x_j^{rs} \\ & - \sum_{s \neq r, j} a_{\tau j}^{rr} x_j^{sr} \geq 0 \quad (r = 1, \dots, m) \quad ; (3) \end{aligned}$$

$$\sum_j \dot{l}_j^r x_j^r + \sum_j l_j^r \bar{x}_j^r + l_\tau^r x_\tau^r \leq L^r \quad (r = 1, \dots, m) \quad ; (4)$$

$$\underline{d}_j^r \leq \bar{x}_j^r \leq \bar{d}_j^r \quad (\text{for some } j, r);$$

$$\dot{x}_j^r \leq N_j^r, \quad \dot{x}_j^r, \quad \dot{x}_j^r, \quad \dot{x}_\tau^r, \quad x_j^{rs} \geq 0 \quad (5)$$

$$Z \rightarrow \max \quad . \quad (6)$$

Besides, the model can include constraints on amounts of capital investments for the entire planned period (H_j), which are substantiated in point models of national economy:

$$\sum_{r,j} h_{ij}^r \bar{x}_j^r \leq H_i \quad . \quad (7)$$

Proceeding upon a definite law for investments growth over the planned period, the investments of the previous year and their sum total over all the year can be expressed as functions

of known investments of the base year \dot{u}_i^r , and unknown parameters of the annual growth of investments ρ_i^r

$$u_i^{Tr} = (1 + \rho_i^r)^T \dot{u}_i^r ; \quad (a)$$

$$\sum_{t=1}^T u_i^{tr} = \frac{(1 + \rho_i^r) \left[(1 + \rho_i^r)^T - 1 \right]}{\rho_i^r} \dot{u}_i^r . \quad (b)$$

Substituting (a) and (b) into (1), (2) we obtain a non-linear programming problem. However, a step-wise linear approximation of functions (a) and (b) allows one to obtain linear programming problem with additional constraints. A single solution of linear programming problem gives the solution to the initial problem with the required accuracy.

Appendix 2

VARIANT OF OPTIMIZATION MODEL OF THE TPC SPATIAL PATTERN OF A REGION

1. In the general case the model is as follows:

$$A_i x_{il} - \sum_j \bar{B}_{ij} x_{jl} - \alpha_i x_l - \sum_l x_{ill'} + \sum_l x_{il'l} = \begin{cases} 0 & \text{for } i \in J, l \in L_2 \\ B_{il} & \text{for } i \in J_1, l \in L_1 \\ -x_{il} & \text{for } i \in J_2, l \in L_1 \end{cases}$$

where

- l is the index of production location area,
- $l \in L = L_1 \cup L_2$, and L_1 - being a subset of area through which the TPC external links are implemented;
- i, j - production index $i, j \in J = J_1 \cup J_2$, where J_1 is the subset of region specialization sectors, J_2 is complementary production units of mobile resources;
- $x_{jl}(x_{il})$: intensity of functioning of production unit $j(i)$, located in area l ;
- x_l : labor engaged in area l ;
- $x_{ill'}(x_{il'l})$: deliveries of products from area l (or l') to area l' (or l);
- A_i : output coefficients of production unit i ;
- B_{ij} : consumption of products of production unit i by production unit j ;
- α_i : specific coefficient of consumption of the i -th unit products consumed by manpower*
- B_{il} : assignment for delivery of products of production unit i of specialization sectors out of TPC from area l ($l \in L_1$).

*In all conditions coefficients of variables x_l are recalculated for population size.

2. $Y_{kl} - \sum_j D_{kj} x_{jl} - \beta_k x_l = \Pi_{kl}$ for all k in all l , where
 k is the index of the kind of services of the branches of production and social infrastructure;
 Y_{kl} : development scope of the sector providing the k -th service in area l ;
 D_{kj} : requirement of production unit j in service k ;
 β_k : specific coefficient of population demand for service k ;
 Π_{kl} : assignment for the development level of the infrastructure branch providing service k in area l .
3. $z_{\mu l} - \sum_j R_{j\mu} x_{jl} - \gamma_{\mu} x_l - \sum_k \lambda_{\mu k} Y_{kl} = 0$ for all μ in area l ,
where μ is index of local resource; $z_{\mu l}$ is use of local resource μ in area l ;
 $R_{j\mu}$: requirement of production unit j in resource μ ;
 γ_{μ} : per unit coefficient of the requirement in resource μ ;
 $\lambda_{\mu k}$: per unit coefficient of the requirement in resource μ by the branch providing service k .
4. $x_l - \sum_j T_j x_{jl} - \sum_k \psi_k Y_{kl} - \sum_{\mu} d_{\mu} z_{\mu l} = 0$ for all l where
 T_j is labor resources necessary for the functioning of production unit j ;
 ψ_k : per unit coefficient of labor intensity of service k ;
 d_{μ} : per unit coefficient of labor intensity of utilization of resource μ .
5. Constraints on certain variables or their groups:
 - (a) on import of products of complementary production units and mobile resources from outside the territorial-production complex:
$$x_{il} \leq V_{il}, \text{ for } i \in J_2 \text{ in } l \in L_1 ;$$

(b) on use of local resources:

$$z_{\mu} \leq S_{\mu l} \text{ for all } \mu \text{ in all } l;$$

(c) on use of local manpower reserves:

$$x_l - \hat{x}_l \leq P_l \text{ for all } l,$$

where \hat{x}_l - manpower brought in to area l from outside the TPC, and P_l the local manpower reserve in area l ;

(d) on bringing in manpower from outside the TPC:

$$\sum_l x_l \leq L ;$$

(e) Functional:

$$\begin{aligned} & \sum_{j,l} c_{jl} x_{jl} + \sum_{j,l} c_{il',l} x_{il'l} + \sum_{j,l} c_{il',l} x_{il',l} \\ & \sum c_{il} x_{il} + \sum_{k,l} a_{kl} y_{kl} + \sum_{\mu,c} b_{\mu l} z_{\mu l} \\ & + \sum_l a_l x_l + \sum_l b_l x_l = \min , \end{aligned}$$

where \bar{x}_{il} is the delivery of products of complementary production i (mobile resource) from outside of TPC to area l ($l \in L_1$).

As a result of the solution for each TPC under consideration a layout is determined of the location, scope of development and links of all economic elements, scope and development of use of the resources, for settlement of people, a pattern of the internal TPCs and their specialization.

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Optimization of a Long-Term Program for the Formation
Of a Territorial-Production Complex

A.M. Alekseev and L.A. Koslov

The development of new territories and the reconstruction of the economy of developed regions are generally carried out today by the incorporation of mineral and raw materials in the economic cycle. First, it has become possible to maximize the output of end products through a more elaborate treatment of raw materials. Secondly, scientific and technological achievements are finding practical application in all spheres of production, enabling an appreciable saving in labor. Lastly, in planning the time schedule for the construction of the various units of territorial-production complexes (TPC), it is possible to synchronize the commissioning of the units to maximize the end result, making use of the mathematical techniques of network schedules.

Suppose that for each enterprise being built in the area there is a network graph showing the engineering construction sequence and indicating the commissioning of individual projects. From the network graphs for individual unit construction, a graph for the construction of the complex as a whole can be compiled. The sequence of commissioning individual units in this graph can be regarded as having a high probability. For example, the commissioning of transportation communication lines in the area where a hydroelectric station is to be built should precede the construction of industrial units; felling operations should precede the flooding of an area intended for water storage; individual stages of the power plant should be commissioned before completion of the units to which they will supply power; since workable wood cannot be stored for lengthy periods, wood-working plants should be put into operation before the end of felling; production enterprises should be commissioned after completion of housing and public services necessary for their functioning, and so on. Thus, the sequence of commissioning individual units within the overall complex is of great importance from an engineering point of view.

In a network schedule, a sequence of events differing only in completion time is defined by introducing "fictitious" operations, whose minimum duration is zero. If, in the overall graph for the construction of a production complex, one considers the costs for actual operations, and the savings resulting from commissioning individual units (or their stages) for fictitious

operations,* the problem is reduced to maximizing the overall saving including the costs of construction of all units and the profits accruing after their commissioning. Such a formulation of the problem makes it possible to assess the most economical sequence of commissioning the production units.

The elements of the program depend on available resources and their costs. Since the material resources consumed in implementing a program are normally from different production industries, the optimization of an economic program is the multi-sectorial problem of the composition, and dynamics of resource use that will ensure minimum total costs of production given the time available. In this approach, each admissible variant of economic program implementation has its own sequence, time limit and resource requirement. The optimal path for implementing the economic program is thus the most efficient. It is impossible to obtain estimates of resources for the program from sectorial models without unambiguously defined assignments. On the other hand, it is impossible to determine the optimal consumption of resources used to define sectorial assignments in an economic program without optimal estimates.

These difficulties can be surmounted by organizing an iterative exchange of information between the economic program implementation model and the sectorial models from which estimates for the resource being consumed are derived. In this exchange, assignments for the supplying industries are worked out on the basis of some initial plan of program implementation, i.e., for each industry the parameter Q_t^k , the output of the product k in the year t ($t = 0, 1, 2, \dots, T$) is fixed.

Next their shadow prices (u_t^k) are determined, and used for finding an improved program implementation plan. New assignments are fixed for the industries allowing new estimates to be obtained (see Figure 1).

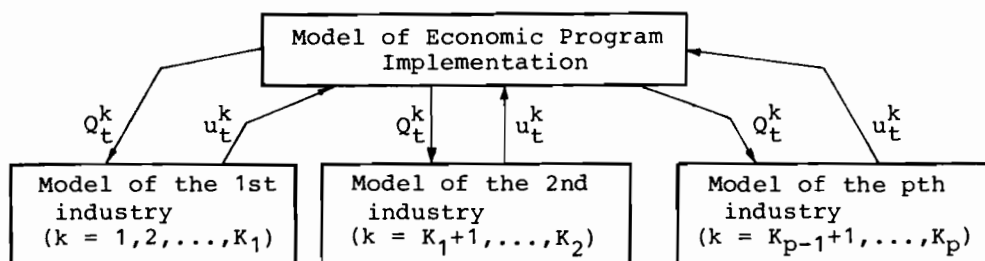


Figure 1. Interaction of models.

*In this case the edges (operations) of the graph will represent economic relations and cannot be regarded as fictitious in the normal sense.

We will consider a model of a multiproduct industrial dynamic problem with continuous variables to be the model of an individual industry.

Notation:

- h = industrial unit ($h = 1, 2, \dots, H$);
- r = the functioning mode of the output ($r = 1, 2, \dots, R_h$);
- k = product manufactured by a sectorial system and appearing as a resource in implementing the operations envisaged by the economic program ($k = 1, 2, \dots, K$);
- t = year ($t = 0, 1, 2, \dots, T$), where T is the time limit for implementing the program;
- a_{ht}^{kr} = output of product k in year t on unit h at a unit intensity of mode r ;
- c_h^r = integral cost involved in the functioning of unit h according to mode r at unit intensity;
- z_h^r = the sought-for intensity of mode r at unit h ;

Minimize the integral cost

$$L(z) = \sum_{h=1}^H \sum_{r=1}^{R_h} c_h^r z_h^r \quad (1)$$

for the conditions

$$\sum_{h=1}^H \sum_{r=1}^{R_h} a_{ht}^{kr} z_h^r \geq Q_k^t \quad \left(\begin{array}{l} t = 0, 1, 2, \dots, T \\ k = 1, 2, \dots, K \end{array} \right) \quad (2)$$

i.e., the sectorial system must provide the economic program with enough resources;

$$z_h^r \geq 0 \quad \left(\begin{array}{l} r = 1, 2, \dots, R_h \\ h = 1, 2, \dots, H \end{array} \right) \quad (3)$$

are conditions of the nonnegativeness of the variables.

The above expressions omit, for the sake of simplicity, many restraints needed for formulation of real problems (limitations

on scarce resources, production capacities, etc.) and contain only conditions which are important for the coordination of sectorial development models and those of the economic program.

For optimizing an economic program, estimates of the resources selected are used, obtained by solving a problem dual to (1-3). The dynamic system of estimates u_t^k thus formed reflects the efficiency of manufacturing product k in year t , and the dual problem can be presented as follows.

Maximize

$$\sum_{k=1}^K \sum_{t=1}^T Q_t^k u_t^k \quad (4)$$

for the conditions

$$\sum_{k=1}^K \sum_{t=1}^T a_{ht}^{kr} \cdot u_t^k \leq C_h^r \quad \begin{pmatrix} r = 1, 2, \dots, R_h \\ h = 1, 2, \dots, H \end{pmatrix}; \quad (5)$$

$$u_t^k \geq 0 \quad \begin{pmatrix} k = 1, 2, \dots, K \\ t = 1, 2, \dots, T \end{pmatrix}. \quad (6)$$

In this pair of problems, the estimate u_t^k can be interpreted economically as the amount by which the costs in the sectorial system are reduced with decreasing plan assignment (Q_t^k). This holds true as long as the change in Q_t^k does not alter the optimal solution.

The estimates are introduced into the model of the economic program as marginal prices, thus making it possible to choose from the admissible variants of the program implementation those which are the most effective for the sectorial system development. This presupposes optimization of the network schedules with time-varying estimates.

Let G be a finite oriented loop-free graph that reflects the process of economic program implementation. The events j ($j = 1, 2, \dots, n$) denote the completion of operations $(ij) \in G$ at time t_j . For each operation the starting time, t_{ij} , and the duration, τ_{ij} , exist assuming $Q_{ij}^k(t)$ to be fixed for $t_{ij} \leq t \leq t_{ij} + \tau_{ij}$. The superscript k indicates the resource

number ($k = 1, 2, \dots, K$). The values u_t^k of the estimates for the k th resource in the year t are given for the entire planning period ($t = 0, 1, 2, \dots, T$).

With this notation, the efficiency of operation ij started at time t_{ij} will be $s_{ij}(t_{ij})$. This value can be derived from the relation

$$s_{ij}(t_{ij}) = \sum_{t=t_{ij}}^{t_{ij}+\tau_{ij}-1} \sum_{k=1}^K Q_{ij}^k(t) u_t^k. \quad (7)$$

Optimization of the economic program consists in finding a time schedule for starting operations $\{t_{ij}^*\}$ that realizes the minimum:

$$\sum_{(ij) \in G} s_{ij}(t_{ij}^*) = \min_{t_{ij}} \sum_{(ij) \in G} s_{ij}(t_{ij}) \quad (8)$$

for the conditions

$$t_j = \max_i (t_{ij} + \tau_{ij}), \quad (9)$$

i.e., the event j cannot occur before all the operations preceding it have been completed;

$$t_{ij} \geq t_i, \quad (10)$$

i.e., each operation cannot be started before the preceding event has occurred;

$$t_1 \geq 0, \quad t_n \leq T \quad (11)$$

are restraints on the duration of the planning period.

Model (8-11) implies that the optimization is carried out taking into account the costs that are nonuniform with respect to time. Therefore, the common techniques of network schedule calculation (3,4) cannot be applied.

For graphs of complicated topology, the model (8-11) can be realized by descent by coordinates, while for elementary graphs, where events follow one another consecutively, or for graphs with no intersections of individual chains of operations, dynamic programming can be used (1). In any of these approaches, it is assumed that during initial data preparation, the earliest possible (t_i^e) and the latest possible (t_i^l) time of occurrence of each event, i , is to be determined, given that the time of completion (T) of the entire complex of operations and the duration (τ_{ij}) of each operation in the network schedule are:

$$t_j^e = \max_i (t_i^e + \tau_{ij}) \quad \text{at} \quad t_i^e = 0 ;$$

$$t_i^l = \min_j (t_j^l - \tau_{ij}) \quad \text{at} \quad t_j^l = T .$$

Since the duration of the operations is not less than the critical path, the starting time, t_{ij} , of the operation may vary within the limits

$$t_i^e \leq t_{ij} \leq t_j^l - \tau_{ij} .$$

From successive values of t_{ij} in this interval, one obtains the dependence $f_{ij}(t_i, t_j)$ reflecting the minimal costs of work in the interval (t_i, t_j) . In each interval (t_i, t_j) the values \bar{t}_{ij} are memorized in the form of the corresponding function $f_{ij}(t_i, t_j)$. The number of possible intervals is determined by the total time reserve of the events i and j ($t_i^l - t_i^e$ and $t_j^l - t_j^e$), or, more specifically, by the product of these reserves. It is more convenient to present the values $f_{ij}(t_i, t_j)/\bar{t}_{ij}$ in a matrix form (see Figure 2). The matrix cells in the technologically inadmissible region (where $t_j - t_i \leq \tau_{ij}$) are not filled in.

After transforming the initial information, in the course of optimization of the program a search is made for a schedule such that

$$\sum_{(ij) \in G} f_{ij}(t_i, t_j) \rightarrow \min ; \quad (12)$$

$$t_j - t_i \geq \tau_{ij} \quad (ij) \in G ; \quad (13)$$

$$t_1 = 0 , \quad t_e = T . \quad (14)$$

t_i	t_i^e	t_{i+1}^e	\dots	t_1	\dots	t_1^l
t_j						
t_j^e						
t_{j+1}^e						
\vdots						
t_j				$f_{ij}(t_i, t_j)$		
\vdots				t_{ij}		
t_j^e						

Figure 2.

Passing from problem (8-11) to problem (12-14), it is possible, without changing the procedure of economic program optimization, to take into account the multivariant nature of resource consumption at each stage. For example, a program stage can be implemented by a number of mutually exclusive modes requiring different sets of resources, or by modes with interchangeable resources. In each of these situations, a specific model for calculating the function $f_{ij}(t_i, t_j)$ can be built so that one can eventually solve problem (12-14).

In coordinating the economic program model with the sectorial system models, it is necessary to suppress fluctuations in link parameters, for which the principle of process braking, investigated in iterative methods, can be applied by adjusting (damping) the estimates u_t^k at two adjacent iterations.* To achieve this, it is advisable at each successive $(\gamma + 1)$ -th step of the iterative process, to work out the optimum network schedule not from estimates of the sectorial system, but from

*Unfortunately, the process cannot be braked by damping the parameters Q_t^k because of the integrality of the problems of economic program optimization.

averaged estimates for all the preceding iterations calculated by the expression:

$$\hat{u}_t^{k(\gamma+1)} = \hat{u}_t^{k\gamma}(1 - \alpha_{\gamma+1}) + u_t^{k(\gamma+1)}\alpha_{\gamma+1} \quad (15)$$

for the conditions

$$\alpha_\gamma \rightarrow 0, \text{ when } \gamma \rightarrow \infty; \quad (16)$$

$$\sum_{\gamma} \alpha_\gamma \rightarrow \infty, \quad (17)$$

where $\hat{u}_t^{k\gamma}$, $\hat{u}_t^{k(\gamma+1)}$ are averaged estimates at iterations γ and $\gamma + 1$; $\hat{u}_t^{k(\gamma+1)}$ is the estimate obtained by solving the sectorial problem at iteration $\gamma + 1$. $\alpha_{\gamma+1}$ is the weight of the estimate at iteration $\gamma + 1$.

The use of averaged estimates in iterative calculations leads to good results (stable values of the functional on successive iterations with the preset error ϵ), but usually necessitates many iterations and does not guarantee a monotonous decrease of the functional of the sectorial problem. In calculations, if the monotonous decrease of the functional of the sectorial model is disturbed at iteration $\gamma + 1$, it is advisable to return to iteration γ and increase the damping of the averaged estimates obtained there by introducing a new parameter $\frac{1}{2}\alpha_\gamma$. A decrease in weight of α_γ by one half usually restores the monotony of the functional decrease.

This coordination procedure has been molded into a unified automated optimization system that has been experimentally tested in the construction program for the Boguchany territorial-production complex (a stage in the Bratsk-Ilimsk project).

Construction of a hydroelectric power station (HPS) is a decisive factor in the development of the Boguchany complex. This, along with a powerful construction and transportation system, make up the base around which mining, metallurgical, timber, and other industries will be built. The resulting power and industrial complex will comprise a number of industrial centers united by a common power, raw materials and construction base. Another important factor in the development of the Boguchany complex is the building of the Reshety-Boguchany railway line to link it with the Trans-Siberian main-line.

Forests are the principal resource of the Boguchany Region. Woods cover 99.4 percent of the area of the Boguchany complex

and so a timber processing integrated plant is to be built on the Angara River in the neighborhood of the Boguchany HPS--a position also dictated by the need to process large quantities of wood in the flood zone of the Boguchany HES. Preparatory work for building timber mills is necessary before starting the construction of the HPS to avoid any wastage of valuable wood.

Table 1 shows the schedule for the construction of production units at Boguchany which minimizes the costs. The model takes into account the possible introduction into the economic cycle of nonmetallic materials for the manufacture of structural elements, as well as the conditions needed for the development of civil engineering products (brick, precast concrete, wood, etc.) when considering the technologically possible limits of growth. Integral reduced costs are used as the criteria for the model of the construction base.

Table 1. Network schedule for the construction and operation of the Boguchany production complex.

- 1 Reshety-Boguchany railway
- 2 Railway from Boguchany to HES section line
- 3 Railway from HES section line to mineral deposit
- 4 Enterprise
- 5 Ore-dressing integrated plant
- 6 Power transmission line no. 1
- 7 Power transmission line no. 2
- 8 HES
- 9 Felling and clearing of felling area
- 10 Timber processing integrated plant
- 11 Woodworking machines plant
- 12 Enterprise
- 13 Housing and utilities complex
- 14 Central heating-and-power plant
- 15 End product

The conclusions about the investment program for the creation of the Boguchany TPC obtained from the calculations are that a most intensive development of the construction base itself must first be carried out, and then housing construction for the future population of the TPC; finally, the construction capacities must switch to building the industrial projects, the mining complex following completion of the woodworking complex.

It should be emphasized that this investment strategy is determined by the particular set of conditions mentioned, so cannot be considered the only correct one. But from the two-level system of models proposed here and the resultant set of computer programs it is possible within a reasonable time span to scan a number of strategies and to select the one which best suits all the additional conditions that were disregarded in the first attempt.

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Optimum Use and Conservation of
Forest Resources of the BITPC

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The Bratsk-Ilimsk Territorial Production Complex (BITPC) is a major contributor to the national economy. In the elaboration of such projects the usual practice is to economically justify the basic parameters and implementation of the system of undertakings. Initially, the development of a specific industry is outlined; attention is paid to such characteristics as development trends and essential interindustry links.

In the elaboration of the BITPC, studies of all forestry branches were made at the sectorial level: timber economy, timber procurement, wood processing, pulp and paper, hydrolysis, and the wood-chemical industry. Besides, problems of transportation, sales, and services of the forest husbandry sector were also studied.

The Master Plan for the industrial development of forest resources in the Irkutsk Region served as a basis for elaborating the development program for the BITPC. In socialist planning practices, the elaboration of such plans for 10 to 20 year periods started before World War II. Thereafter they were developed for all regions, territories and autonomous republics of the country. The plans determine measures for meeting national requirements for wood and wood products, ensuring the rational organization of the timber economy, raising productivity in this field, and enhancing its water protection, conservation, and recreation functions.

The Master Plan for the timber sector of the BITPC determined the overall need of a particular district for wood products. A study was made of the requirements of other regions with respect to the timber industry and to the wood and wood-processing industry.

Based on this assessment of the need for, and the supply of wood, and taking into account economic indices, the Master Plan determined the general scope of timber procurement in the planned period; the amount of timber procurement for operational regions and subregions; the scope of wood-cutting for individual industrial forestry enterprises, including the composition of their raw material base, and the transportation development pattern; location, composition of production branches, and capacity of wood-processing enterprises; a list of forest management undertakings; and the order of priorities for designing, building, and implementing other measures envisaged.

The document also determined the amount of capital equipment and manpower resources needed for forest management.

Recommendations of the Master Plan regarding the BITPC were further given in a series of technological and economic directives which supplemented the overall plan for the development of forest management and the timber industry. For example, they stipulated where enterprises should be built, their production capacities and products, the criteria for the supply of raw materials, semi-finished products, fuel, electric power, and water, and the technological and economic indices of production and construction of individual enterprises. One of the basic requirements set forth was that timber enterprises pay particular attention to modern scientific and technological developments.

The final part of the development program for the BITPC contained detailed plans for constructing each project. These documents presented solutions to technological, organizational, and economic problems, and dealt with problems of raw materials and construction, as well as the future activities of the enterprises and their respective units. Taking part in this exercise were design, research and industrial management institutions as well as Party, Soviet, and other organizations.

STRUCTURE OF TIMBER INDUSTRIAL COMPLEXES

Experience has shown that the creation of timber industrial complexes is the best organizational form for forest management of the BITPC. A timber industrial complex is an integrated, economically substantiated system of enterprises organized for the development, use, and conservation of forest resources of a region, based on joint production, specialization, and cooperation. Thus a forest industry complex was set up with integrated wood-processing plants and specialized enterprises, a wood-collecting forest transportation network and industrial forestry centers, interconnected by an integrated rational supply and sales system.

Design models are the main method for identifying optimum capacity of an enterprise. There were twenty-eight draft design models of enterprises with annual production capacities ranging from 50,000 to 1 million m^3 and exploiting raw material bases with liquid wood reserves of 1 to 80 million m^3 ; practically all combinations of production output and sizes of raw material bases were considered. Draft design models of pulp and paper production were elaborated for assumed raw materials deliveries of 1.5 to 12 million m^3 .

Based on this research, it was decided to establish a timber industrial complex for East Siberia with an annual processing capability of 2 to 4 million m^3 , or 6 to 8.5 million m^3 of raw materials. Because the forest sector is linked with other branches

of the national economy, it was believed feasible to increase the concentration of raw materials to 6 to 7 million m³. Studies showed that establishing two timber industrial complexes, one at Bratsk and the other at Ust-Ilimsk, would be highly efficient.

STRATEGIES FOR DEVELOPING THE FOREST SECTOR OF THE BITPC

Modern mathematical methods have been broadly used for determining strategies for developing forest resources in East Siberia, including the BITPC. Research and design institutes participated in developing this program. The optimization scheme for the forest and wood-processing industry, and forest management, is based on a system of models for planning optimal territorial-production suggested by Academician Aganbegyan. This system of models includes high level (national) models and lower-level (sectorial, regional) models (Table 1). The forest sector is the main object of optimization at all levels and for all groups of models. This condition is achieved through detailed treatment in all models, varying the factors of its development, etc. National economic conditions and links appear in this approach as a background against which the forest sector is functioning.

Table 1. Timber complex optimization.

Plan- ning level	Groups of models		
	A	B	C
I	Free territorial planning of the national economy	Planning interregional location of timber industry production	Functioning of individual branches of the forest industry
II	Free planning in an individual region	Interregional planning of a complex of timber industry branches	Functioning of separate branches in a region
III	Planning territorial-production complexes	Creation and functioning of timber industrial complexes	Functioning of separate production units

A description of the problem of the interregional development of the forest sector, as realized for East Siberia including the BITPC, is given below.

The problem may be represented by a system of blocks describing the conditions of woodcutting and processing within the territory under research. All the blocks are interconnected by the conditions of production and transportation (Figure 1). The problem may be stated as follows.

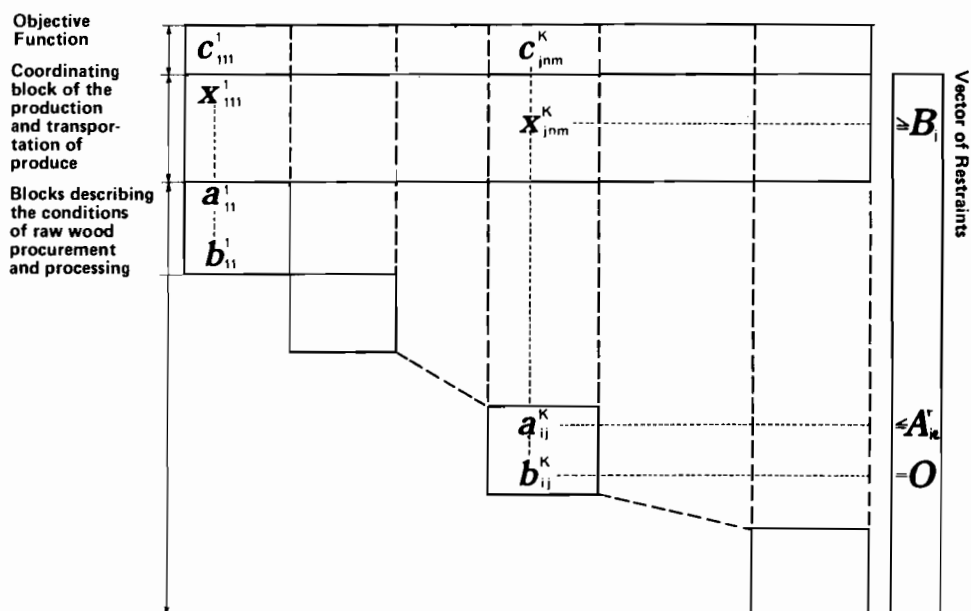


Figure 1. Matrix structure of the problem of the long-range intraregional development and location of forest industry branches.

First, all forests of the region being studied, for each forestry and timber procurement establishment are subdivided into groups (I,II,III) and categories (operational, protective, forbidden, wood stock of the quality class Ya and Yb, etc.). This division is done separately for short- and long-term planning. Forests are assigned to one group or category, according to existing norms and legal provisions with due account of probable changes in the future.

Secondly, each of the forest fund sections is characterized by a set of variants for rated wood-cutting areas (all differential kinds of use are specified). An initial level of wood cutting is made on the assumption that in the rated years certain criteria for forestry development are met (e.g., appropriate allocation of capital investments, machinery, manpower and other production resources) and that the requirements concerning the inadmissibility of lowering the attained level of timber procurement at the raw material bases of the operating enterprises are observed (except the cases specially stipulated by standard procedures, e.g., exhaustion of reserves).

An upper limit on cuttings is set for the region in the event of the broad application of forest management methods.

Other variants of the rated cutting area are intermediary. The variants of the level of the rated cutting area were determined in line with the methods for calculating forest exploitation level in the woods of the USSR State Forest Fund, and with recommendations of research institutions, the State Committee for Forestry of the USSR Council of Ministers, and other organizations. The effect of biological factors on forests must be considered as main constraints.

Listed for each plot sector are forest management and other measures necessary for ensuring the continuous forest exploitation during the implementation of the appropriate variant of the rated cutting area, taking into consideration capital outlays for such factors as land reclamation, and the introduction of fertilizers.

A set of variants of permissible cuttings is given for each plot with an indication as to their use, the permitted scope of cutting according to reserve, degree of cutting and other characteristics dictated by the requirements of silviculture and practice.

A pattern of wood procurement is drawn up for each plot and cutting method, both for coniferous wood and for leaf wood (by component breeds); this covers the following items: soft workable wood (14 cm, 14 to 25 cm, 26 cm and more); leaf workable wood (14 cm, 14 to 25 cm, 26 cm and more); and low grade softwood and leaf wood.

When calculating operational and capital outlays for the development of each plot, account is taken of the average volume of stem trunk; the mean reserve of wood per hectare of the operational and the total area; the composition of wood stock (coniferous, leaf-bearing, mixed), and distance for hauling the wood to the nearest railway station and district center.

For determining adequate forest reproduction measures, the territory is divided into sections in terms of the kind of forest, with an indication whether the areas can be easily, satisfactorily, and poorly restored after clear felling. A description is given of the desirable composition of future forest for each plot.

Specific operational, capital, and reduced expenditures for all subunits of the forest sector, including the given forestry, are determined for each plot (and its exploitation variants).

Based on preliminary analyses, possible sites for locating wood-processing plants are mapped out. For each type of product, a possible mode of production is determined taking into account consumption rates of raw materials, waste yield, and use of other resources. These methods differ in terms of raw material consumption rates, interchangeability of raw materials, and use of other resources (labor, water, fuel, and power).

In the selection of a site, account is taken of the following main factors: availability of raw materials, transportation conditions (locations of the nearest railway station or district center), conditions of delivery of raw materials from neighboring districts, water supply, existing building sites, infrastructure level, etc.

Consumers of finished products are found both within and outside the district. Each consumer is measured in terms of the quantity and the assortment of products required. Consumers with similar supply conditions are aggregated into large territorial units.

The demand for wood products is calculated for each period, based on data on both the future development of the national economy of the region (e.g. scale of industrial production and building, population) and on the estimated rate of wood materials consumption for individual categories of consumers. These data are then adjusted in terms of the estimated optimal indices for the development of industrial timber production on a national scale.

In the region being studied, the volume and kinds of cuttings, the pattern of wood procurement, and the scope and pattern of wood-processing production branches are determined so as to meet the requirements of all consumers (with the product items specified) at minimal reduced costs. This is a static, multiproduct, production and transportation problem, with continuous variables, which is solved by a criterion of minimal reduced costs for the individual years of the planned period. Its appropriate model is formalized as a general linear programming problem.

The solution to this optimization problem made it possible to determine the following:

- Location points, composition, and capacity of wood-processing enterprises including the Bratsk and the Ust-Ilimsk timber industrial complexes;
- Composition of the timber raw material base of each wood processing enterprise, and the optimal production level of all industrial forestry centers;
- Forest exploitation conditions, scope, and character of silvicultural measures.

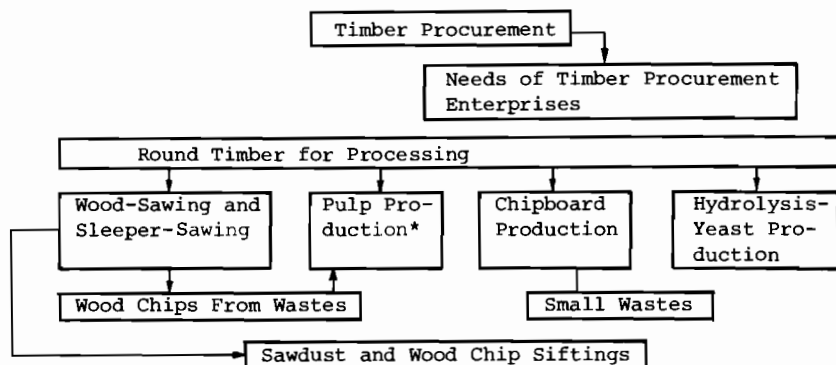
Optimization calculations have confirmed the main conclusions of the Master Plan, and the most important technical and economic substantiations of the BITPC program. In addition, they made it possible to specify certain strategic principles for exploiting and reproducing the forest resources over the long term.

DEVELOPMENT OF THE FORESTRY SECTOR OF THE BIPTC

Taking into consideration the composition of timber bases and in line with the principle of their permanent use, the annual volume of timber procurement and the respective volume of wood processing have been determined. For the Ust-Ilimsk complex, it is 6.3 million m.³, for the Bratsk-complex it is 6 to 7 million m.³; these figures take into account that certain wood is delivered in round form.

Once the enterprises of the Bratsk and the Ust-Ilimsk timber production complexes are operational, they will produce a wide range of wood-sawing, wood-processing, pulp and paper, hydrolysis and wood-chemical products, as well as pulp of various kinds. Because the timber industrial complex includes a group of interconnected enterprises, it is possible to use raw wood in the fullest and most efficient way (Figure 2).

Use of Wood at the Ust-Ilimsk
Territorial Production Complex



* Pulp production also receives woodchips obtained from wastes after bucking stem trunks.

Figure 2. Use of wood at the Ust-Ilimsk Territorial Production Complex.

The experience gained in creating timber industrial complexes in East Siberia has shown the high economic efficiency of these complexes despite the fact that construction was carried out under severe conditions of Siberia, with relatively high capital investments and production outlays.

Forestry Utilization

Continuous use of forest (wood) under the conditions of the complex is ensured owing to planned timber procurements and uniform wood-cutting. Since mature and over seasoned stands prevail, one can make use of such wood cuttings and thus ensure long-term felling (for 60 years). This is sufficient time for the reserves of the operational fund to be replenished by the maturing of young stands. According to Giprolestrans estimations, the maturing of stands will help to maintain the resources in the area for another 40 years. Thus, forest can be exploited on the planned scale of timber procurement for the entire cycle of cuttings, with the exception of the coniferous species on the territory of the complex.

It is planned to increase the scope of exploitation by expanding forest reproduction work and by increasing the productivity of the crop. At the BITPC, attention is given to preserving second growth during wood-cutting, tree planting, and sanitation cutting.

Trees are currently planted annually on the territory of the BITPC on an area of 9,400 hectares, and second growth is preserved during wood-cutting on an area of 30,000 hectares. These measures directed at accelerating the reproduction of forest resources cover 71 percent of the total cutting area. On the remaining part, natural reproduction is expected in three to five years after wood-cutting. The annual volume of work on forming optimal composition and enhancing growth through sanitation cuttings is now 11,600 hectares. This will undoubtedly enhance the productivity of the forest resources of the complex and increase the scope of the future use of these resources.

The following criteria are necessary to fully use all the useful properties of forest stands during the life span, under the conditions of the Bratsk-Ilimsk Complex: a) preservation of water-protecting, water-regulating, sanitary-hygienic, aesthetic, protective, and other properties of woodstands during wood cutting; b) tree boxing and procurement of resin for chemical production; c) gathering of mushrooms, berries, medicinal herbs, and other nonwood plants; and d) hunting.

Ten enterprises are engaged in boxing on the territory of the BITPC over an area of 290,000 to 300,000 hectares of pine stands. Three commercial co-operatives in the area are engaged in hunting and forest harvesting.

The need to preserve and improve forest protective properties is most important in the use of forest resources. The forest fund is therefore divided into groups depending on the importance of its particular sections for the national economy.

The BITPC forest fund belongs to groups one and three. Group one is made up of forests that provide protective belts along river banks, motor roads and railways, and green belts of towns. A special regime for wood reserve use has been established for this part of the forest fund, subject to the rules of the principal produce. Wood-cutting here should facilitate restoration and enhancement of the protective properties of the forest, and ensure replacement of those tree stands that fail to perform their functions, by young stands of an optimal breed structure.

The remaining territory of the complex is classed in the third group of forests, used mainly for meeting the national requirements for wood. The protective properties and forest environment conditions are preserved here by regulations on the width of tracts being cut, specific times for joining felling areas with transportation lines, and cutting methods. On certain forest tracts with special protective importance, wood procurement cutting is prohibited; these include river and lake bank protecting belts trees on slopes.

Systems Approach and Mathematical Models
For Integrated Regional Development Planning

A. Straszak

An important part of IIASA's research focuses on the application of a systems approach and mathematical modeling to real, contemporary, complex socio-economic and technological objects.

In many countries it is recognized that the creation of a new industrial region or subregion requires more sophisticated planning and programming instruments. In most countries, the very large-scale regional development undertakings have assumed national importance.

Industry, agriculture, transportation and other sectors of national economy are individual, complex and coherent subsystems that together form a larger system, usually the national one. The same applies to geographic space, administrative or territorial regions that become significant in national dimensions, or that enter into direct contact with a national system and become elements of that system.

IIASA's work with the use of mathematical models and computers for integrated regional development has until recently been limited. We were fortunate to begin our studies with two important regional programs: the Tennessee Valley Authority (TVA) in the USA, and the Bratsk-Ilimsk Territorial Production Complex (BITPC) in the USSR.

This Conference provides us with the excellent opportunity to share the experience in systems approach and mathematical modeling of the Institute of Economics and Industrial Engineering of the Siberian Department of the USSR Academy of Sciences. This experience was gained in the course of developing the BITPC and other territorial production complexes (TPCs) in the Soviet Union, mainly in Siberia.

The concept of a territorial production complex has been very useful in the creation of new industrial regions. This concept is a multidimensional one. Some of its dimensions have been discussed elsewhere in this volume, and I therefore shall refer to only two: the *systems approach* and *mathematical modeling*.

The combination of a systems approach with the extensive use of mathematical models--even very simple ones--is a powerful tool

for an integrated approach to regional development planning and management. In general, integrated regional development programs should include the following: systems approach, mathematical models, computer applications (in slightly different perspective), integrated planning, integrated financing, and coordinating procedures.

Why is the systems approach important to integrated regional development? Any integrated regional development program should account for national, sectorial, and regional problems. When analyzing each country as a socio-economic system, we may subdivide it into elements of sectorial and regional character. This is the core of the systems analytic approach elaborated at the USSR Institute of Economics and Industrial Production. The approach was tested in the case of the BITPC and in other territorial production complexes. The first step consisted in systematically analyzing the national economy and identifying its elements and their interconnections. The second step was more important from an instrumental point of view. Considerable efforts were involved in mathematical model building at different levels of the system and for different hierarchies.

At the national level, two mathematical economic models are needed: a "point" sectorial-national economy model, and a spatial (territorial) sectorial-national economy model.

Even in different socio-economic environments, there is a need for models of a national economy in regional development planning. National models have been incorporated in the TVA regional planning system of models designed in one of the TVA divisions. It has been shown that mathematical models of the national economy are important for comprehensive integrated regional development planning.

What kind of models? How many of them? What level of aggregation should be used in such models? These questions remain open. New and effective instruments are needed to solve the problems of interrelations between national, sectorial, and regional models.

There are different types of models that should be taken into consideration; they may be static or dynamic, deterministic or stochastic, linear or nonlinear, descriptive or optimizing. For integrated regional development planning the design of the models should be simple; an example of this is seen in the case of the BITPC.

Mathematical models of the national economy play only a limited auxiliary role in planning and management. Hence, in my opinion, a set (consisting of more than two) of national models is needed.

In studying the nature of the breakdown of the national economy, we must take into account the following:

- Sectors and regions (macroregions) can be broken down into subsectors (branches) and subregions;
- Subsectors (branches) may be broken down into groups of enterprises, which constitute the final level of the breakdown;
- Subregions may themselves be medium-level administrative units or geographic-economic territories.

Such breakdowns usually involve the appearance of two or three structural levels. In the BITPC, enterprises (self-accounting productive units) and administrative territorial areas are at the bottom level. The bottom level objects of sectorial and regional breakdowns are essential elements of a TPC, which is regarded as a system. When the TPC concept was introduced and tested for new industrial regions, most of the bottom level elements of sectorial breakdowns were new, and in general, the conditions of regional development were also new. Since the development of new industrial regions has a national dimension the TPC's system becomes a part of the national breakdown.

In the national economic planning system of the USSR and other countries, entities such as multisectorial national programs are used. The Soviet presentations have shown that each TPC is characterized by three dimensions or aspects: national, sectorial, and regional. To integrate these, comprehensive mathematical models of the TPC and its environment for all stages of TPC development are needed. The BITPC experience has shown that since the planning of the development of a region is a multi-stage process, there is a need, at each stage, to have a set of comprehensive economic mathematical models.

To summarize we can state that the TPC concept may be effectively used when a set of appropriate mathematical models is available.

Though the need for models seems to be obvious, model building is still in its early stages of development in almost all countries. The following question arises: What is the minimal set of models needed to implement the TPC concept? Experience gained during the TVA case study and during the first steps of the BITPC study has shown that models of the national economy, population and manpower, agriculture, and spatial and production planning form the basic core of the set of models. In the BITPC case, because of the need for a detailed plan based on optimal model solutions, many additional individual models were required. (Two further questions that should be answered in connection with the aggregation of models are: What should be the scope of the aggregation of models, and what is the experience in the Bratsk-Ilimsk case with their aggregation and disaggregation?)

It would be interesting to know the opinions as to the life-span of specific mathematical models and hence when the new generation of mathematical models for TPC is expected to appear.

Since all the models being discussed are meant to help in management and planning, it is important to know the characteristics of the interface between the management and planning structure and the model structure. In order to ensure the smooth and efficient interaction between the two structures, they must be closely related to each other. In the BITPC case, we observed efforts to satisfy this requirement. Similarity in the model structure and that of management and planning is the key factor in ensuring the successful implementation of the model's solutions in integrative planning. The impact of systems analysis and modeling techniques on management and planning requires further study. While it is obvious that mathematical models will play an increasingly important role in socio-economic and technological systems, and in particular at the regional level, we must be aware that the interface problems that arise between the model and the user may delay progress. Systems analysts and model builders should take into account to a greater extent the needs and capabilities of the model user.

The experience of both the BITPC and the TVA has shown that the development of a new industrial region requires long-, medium-, and short-term programming procedures. Model builders must obtain information as regards time horizons of mathematical models. Planning and forecasting models of 1, 5, 10-15, and 30-50 years are needed. Of course, time horizons introduce a new dimension of the breakdown of the system, and hence of the classification of models. The concept of TPC determines only the first stage of the establishment of an industrial region. When the TPC is fully established (in the BITPC case this may be 10-15 years from now) then, in my opinion, new mathematical models are needed that take into account the development process of the TPC.

Models for Regional Development Planning

J. Owsinski

STATEMENT OF THE PROBLEM

Complex and also physically large systems may be characterized as multidimensional, multiobjective, and multilevel. We are not yet able to construct a single model that reflects all facets of such complex systems. In order to help in the management of large organizations or undertakings, we are therefore designing partial models that describe or optimize relatively limited scopes of actions within the system. A single overall model can exist only as a certain superposition of partial models.

The partial models that have been developed and used are based on a specific methodology and approach, appropriate for a given modeled element of the system. It is of great interest, however, to assess the methodology for the development and use of models on the higher level of analysis, on the level of the whole system. To do this, we should consider as appropriate wholes both the complex system which is the object of modeling (*the object system*), and its reflection provided by the system formed of its partial models (*the model's system*).

In order to monitor and control the models' development and use, it is necessary to identify general features of the structure and dynamics of the interface between management and the models' system.

THE APPROACH

We begin by analyzing the models' system (Figure 1); we must first identify its elements. These elements are individual models and homogeneous groups of models. Each element of the system is characterized by a fairly limited number of features that enable us to estimate roughly the model's function, type, importance, and use. A "table of models" is therefore established for each case studied. For example, the table elaborated for the Tennessee Valley Authority case consisted of a sample of 65 items out of several hundreds existing in the organization. The sample was taken on the basis of current or prospective relative managerial importance of the models. On the bases of our present knowledge of the Bratsk-Ilimsk case, a table of models pertaining to Bratsk-Ilimsk Territorial Production Complex (BITPC) was drawn up; it has been distributed among participants of this Conference as a means for further discussion of the subject. The table refers to

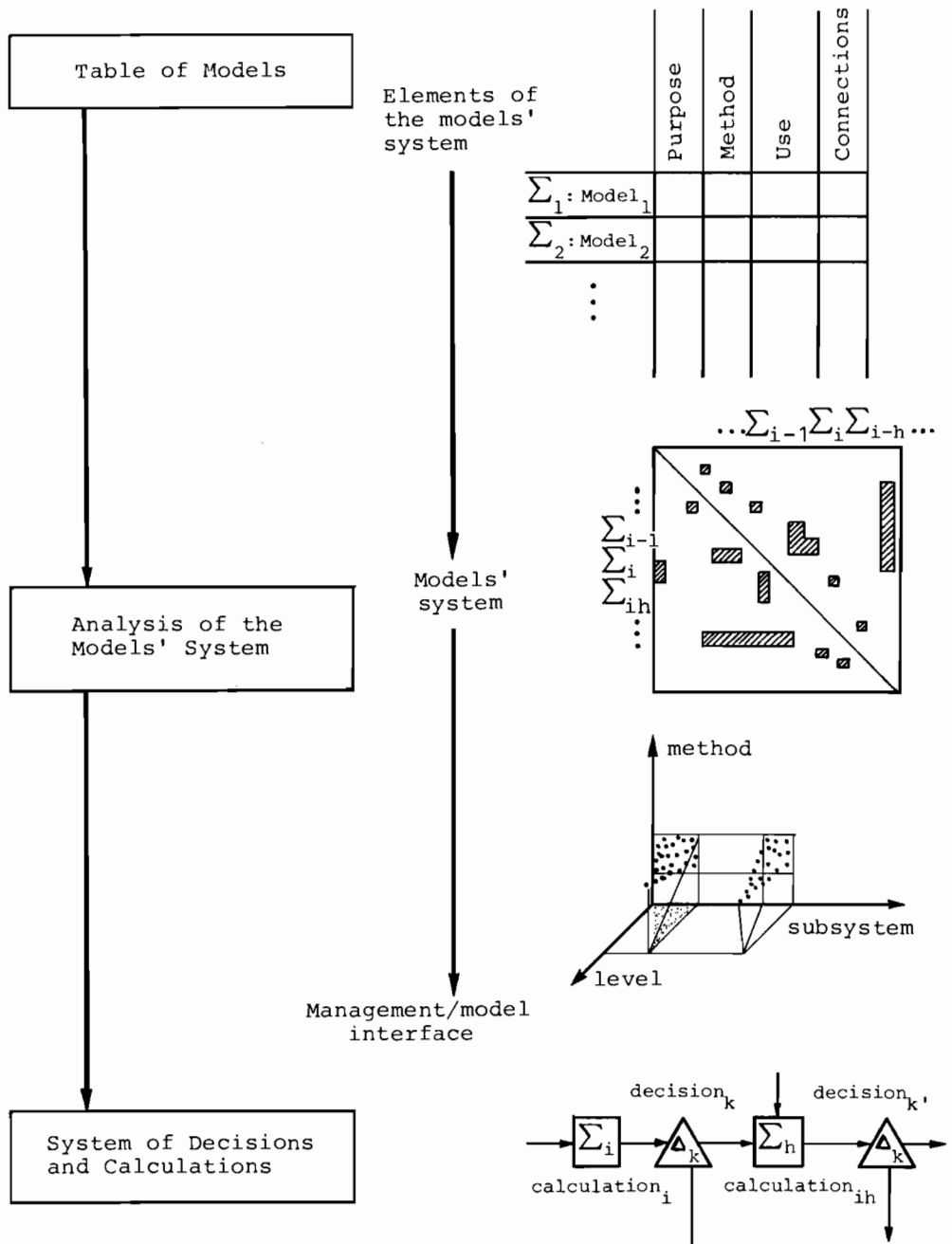


Figure 1. Models' system.

those models that have been presented in the Conference papers. It contains more blanks than filled-in spaces, and we hope that further research will enable us to better understand the models' system.

Models' System and the System's Structure

The next step in the analysis of a system is the identification of interlinkages between elements, and hence in the modeling of the system's structure. We are considering existing forms of interconnections, and also trying to recognize potential and future connections and to estimate existing trends. The easiest way to assess connective properties of the system is to analyze its connection matrix. Deeper insight into relations between models can be achieved by mapping identified models in the "models' space". This space is spanned by the models' characteristics such as that part of the object system which they reflect, the physical and temporal stretch of relevancy, and methodology. Distribution of the models in space and the dynamics of this distribution reveal very important features of both the models' system and the relationship being analyzed.

At the same time that we are elaborating the table of models and analyzing the models' system structure, an effort is made to position the models' system and to separate models in terms of the planning and decisionmaking processes (Figure 1). As a result, we are able to draw up a general overall system structure which shows the major groupings of models, the most important connections, and the sequences of use. The structure therefore reflects the outlook of the highest level of the models' system.

System of Decisions

In the final stage of analysis we try to map the models' system into a managerial process in a specific way. This is done by identifying the managerial inputs to the models and by using the results of individual models. Assumptions made prior to the activation of model and decisions based on its results are not yet formalized (or formalizable) human actions. By interconnecting these actions (decisions) of management with the models' calculations, we form a system of decisions and calculations (SDC), the main tool for assessing model/management interface.

The approach as depicted above distinguishes two main problem areas, subject to appropriate research: the characteristics of the models' system, the embedding of this system in the planning and decisionmaking processes. I shall present some points of interest and questions connected with these problem areas focusing mainly on the models' system. Elsewhere in this volume, Straszak analyzes the models' system in terms of the overall economic system, as seen from the national and the regional points of view.

The Models' System

A major characteristic of the set of models described in the Conference papers is the existence of a unique (in scope and sophistication) system of models for regional planning. This system is a result of an imposing effort undertaken at both the regional and the national levels to establish a system for national socio-economic planning. Within this framework, the USSR Institute of Economics and Organization for Industrial Production has conducted substantive work on both national and regional elements of the system. Specifically, a series of national level models have been designed coupling the sectorial with the territorial breakdown of the economy. These models maximize, in the words of their authors, the national nonproductive consumption.

At the lower level of planning, the system of models for regional purposes was elaborated. Resulting from this system are the bases for the plans and design schemes of the intraregional, TPC production, and infrastructure patterns. Throughout this second level system, the investment outlays for setting up planned elements of a regional socio-economic structure are minimized.

Note that the models' system structure was designed to fit the appropriate structure of planning tasks in long- and medium-term planning.

The system has high connectivity (about 10%, while the minimal systemic level for the set of about 25 elements is 4%) and high methodological homogeneity. It is one of the very few examples of a system with such high connectivity. This degree of connectivity seems to make it necessary to apply special measures to ensure the appropriate functioning of the system. From this point of view, it would be interesting to learn about problem solving with the use of the whole system. (For example, was an additional effort needed to ensure data compatibility and coordination of solutions?) Also, are any supervising devices planned for the near future (e.g., system management software)?

Another question connected with the models' system and its functioning under different conditions refers to flexibility. This question concerns mainly methods used in model building. We are interested mainly in a regional planning system, which is methodologically very homogeneous, and based primarily on linear programming. Obvious questions then come to mind: how does one take account of stochasticity, dynamics, and nonlinearity? The system is generally used for long- and medium-term planning, since this is the perspective in which the TPC appears. It is the temporal dimension that underscores the importance of the three mentioned features.

The flexibility of the system could also be further enhanced through the introduction of software which allows for direct, conversative communications with individual models and their sequences. This will enable not only fast verification of plan

alternatives by the upper level of planning, but also the check-out of sensitivity and preferences of various objects of planning, enterprises, local bodies, etc., in the presence of their representatives. Are there any such modifications of the models' system planned for the future?

Clearly, the idea of the TPC, both in general and for each particular complex, is formulated outside the models' system. What extent then is (or could) the TPC pattern be defined by the input data from previous stages of planning as compared to objective planning capabilities of the models' system?

One of the most interesting ideas put forward within the framework of a system of regional planning models' is connected with the interlinkage of linear sectorial models with the network-type model of project construction (or program realization). It would be interesting to learn more about the economic interpretation of variables exchanged between the levels of the model and about the experiences of using this model in connection with other models from the models' system.

The system's structure has evidently been planned prior to the execution of models belonging to the system. We are dealing then with a conscious system design as opposed to a "natural" system creation. The latter is usually connected with purely instrumental usage--in operative and mostly day-to-day activities. In this case, mathematical models and computer applications are used in as much as their immediate efficiency has been widely recognized. Formation of the models' system is then the result of the growth of individual applications and occurrence of links resulting from overlapping or organizational coordination (Figure 2). Both the conscious design approach and the natural creation process have their merits and shortcomings. Applying the former, we avoid additional effort of interlinking separately developed and differing modules. These separate modules, on the other hand, may present a variety of methods and formulations best suited for individual applications if developed in a "natural" way by different users. The problem that arises may be stated in the following way: within the framework of the conscious design approach used for developing the models' system presented, it would be good to organize the iterative procedure of design, testing, and modifying with the participation of the designing body and users (Figure 3). How did such a procedure work in the Bratsk-Ilimsk case, and what were the conclusions reached by the model builders? Did this procedure include local bodies? We shall return to the question of users later on.

In the set of models described in these papers, a future consistent system of models has been presented. It is connected with the power system and the appropriate sectorial planning process. It would be interesting to know at what level and with what means is the linkage of this system with the regional planning models' system going to be brought into being for the BITPC.

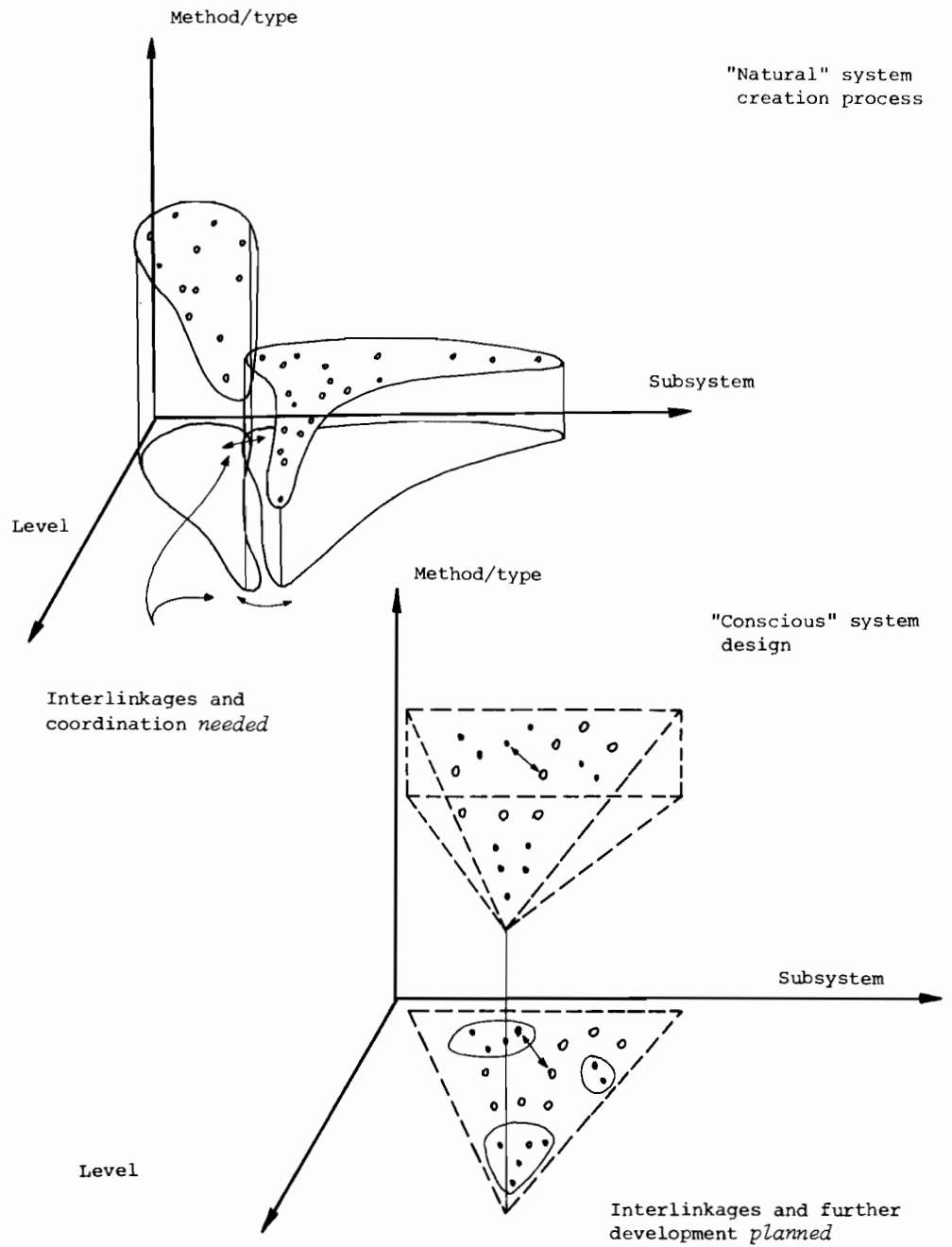


Figure 2. Formation of the models' system.

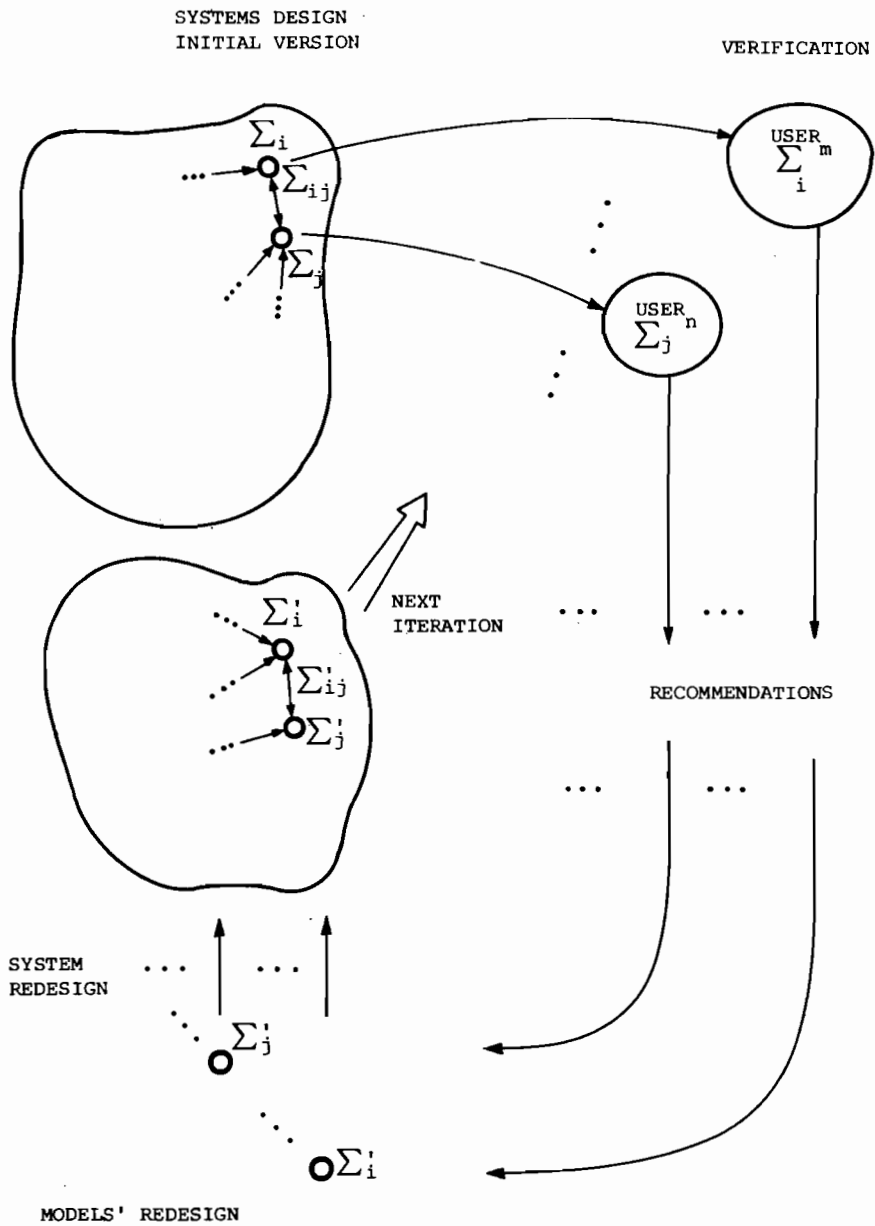


Figure 3. Models' system through user evaluation.

Embedding in Planning and Decisionmaking Processes

The last problem mentioned has brought us to the problem area of model/management interface.

If we try to map the general structure of the regional planning models' system of the BITPC into the analogous framework shown for the TVA case we can see that the diagram obtained is more complex (Figure 4). One of several causes is that, in productive operations, sectorial organizations play the major role. In particular, referring to the two models' systems mentioned before, we state that they originated from two different organizational sources. Therefore, the question of the models' interlinkage is also the question of organizational coordination and as such is treated in organizational analysis.

Further analysis of the two systems leads us to state that in the power planning system more of a "natural" development process has been observed than in the regional planning system. This fact stems from the need for instruments of planning and decisionmaking in sectorial bodies having direct operational management authority and responsibility for objects of management. The regional TPC planning system could not be developed in a natural way by any organization having responsibility or authority in the TPC's development because such an organization does not exist. (In reality, the sectorial power system, in its regional segments, is not very much bound to the TPC.)

There is no organization at a regional level directly responsible for TPC development, and there is no single, unifying planning document. For whom then is the TPC planning system as a whole meant? What institution has enough planning power so as to use sensibly the results of the models' runs? Retracing the administrative structure we can see that the institution is either Republic or Union Gosplan. From the point of view of long-term planning and forecasting--where the TPC design belongs--who are the users who verify the TPC planning system by applying their own measures to models' solutions?

One such local user has been proposed elsewhere in this volume*: it is the organization that will have enough power to plan and manage the development of BITPC, be it in the form of an appropriate administration authority or the construction enterprise, Bratskgesstroi, vested with additional responsibilities. These propositions reflect the need to properly structure the organizational space in the region. They stem from the conviction that the introduction of large-scale, specialized industrial investments in the region, with its low economic activity, should be accompanied by analogous changes in organizational space (Figure 5). High organizational entropy connected with low

*See V.P. Gukov and N.G. Perevalov, *Management of the BITPC*; and G.M. Filshin, *Implementation of a Long-Term Program for the Development of the BITPC*, both in this volume.

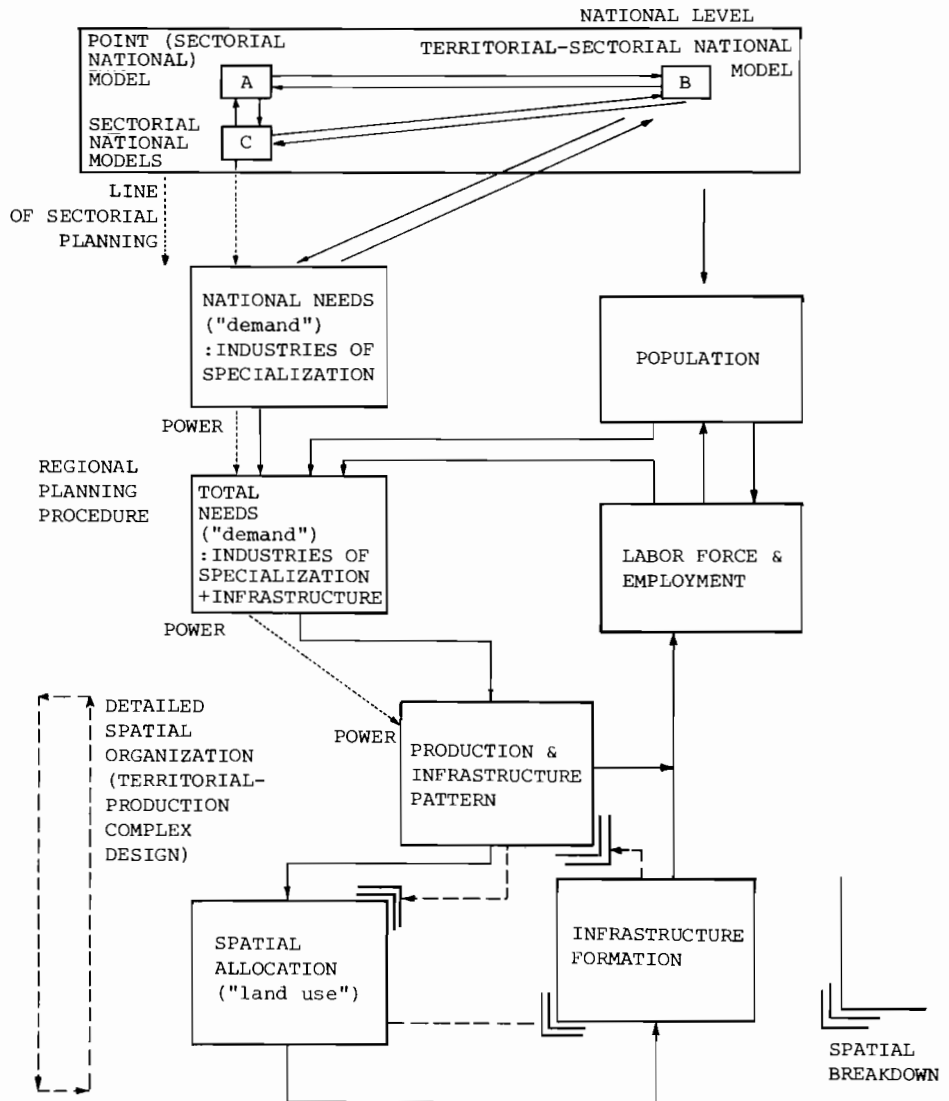


Figure 4. General structure of the regional planning models' system of the BITPC.

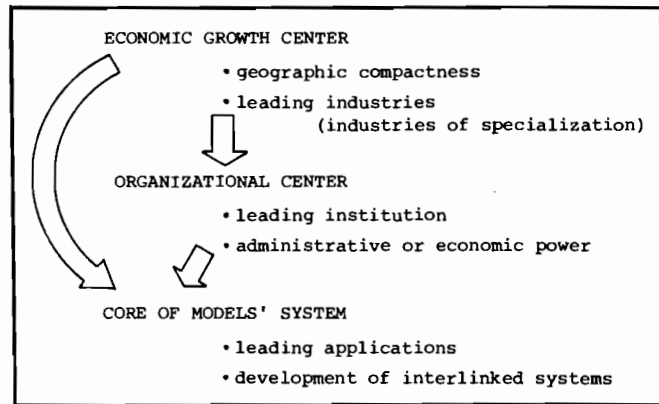


Figure 5.

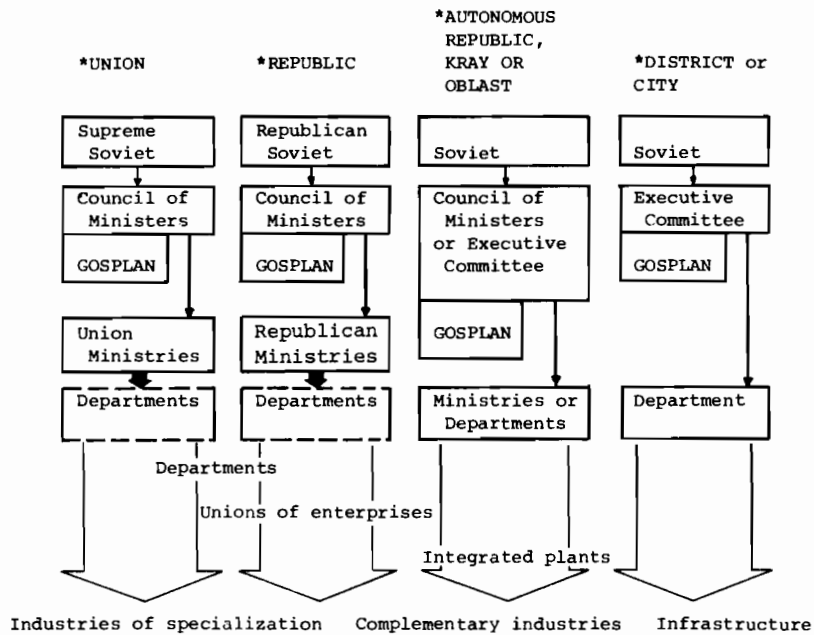


Figure 6. Projection of authorities of various levels in the region (planning relations not accounted for).

economic activity in the predevelopment period is perceived on the subregional level as "white noise" of various organizational elements originating above this level (Figure 6). This perception may happen even in conditions of well-defined organizational structure. The entropy must then be decreased in order to match the new economic situation of territory.

The computational reflection of such a new organization of new interorganizational mechanisms already exists--it is the regional TPC planning and design models' system. The question is: what effect will it have?

A Simplified Framework for the Use of Models in Planning†

Wm. Orchard-Hays

Much of the difficulty of commenting on the three previous papers is caused by the unclear definition of what is meant by system analysis, and by the overuse of the word "model", and perhaps also of "optimization". Not all planning and system analysis involves models in a narrow or specific sense. To me, a model is a conceptual representation of some aspect of reality; it consists of data structures and mathematical or logical processes that can be computerized. It may or may not involve optimization, and the use of a model may sometimes stop short of actual computerization. As regards the models discussed in these papers, computerization is clearly an inherent assumption.

One can distinguish five major stages in the process of project planning using such models. The first level is called *decision analysis*. This level might take other forms, but it must be the genesis of the whole analytical program and set its purposes.

The second stage might be termed *strategy formulation*. No complex undertaking is done from scratch in a vacuum. This stage has two main considerations: existing political and economic forces and their linkages; and dependencies and requirements with respect to time. Whether or not specifically recognized, this stage exists in either a socialist or a capitalist framework. The details may differ which may account for some difficulty in understanding each other's systems. The important point, however, is that this stage already determines the questions that models must answer, because it determines whom the answers are for and at what level of confidence with respect to time. Thus a model used in defining a five-year plan that has the effect of law will differ from one used to prepare a prospectus for a speculative investment, particularly if the latter has a potential escape in the form of a later subsidy.

The third stage is *formulation of a conceptual model of reality*. In terms of systems analysis, "reality" is always an

†Comment on A.G. Granberg, and M.K. Bandman, *Modeling of Territorial-Production Systems: Case Study of the Angara-Yenisei Region*; on A.M. Alekseev and L.A. Kozlov, *Optimization of a Long-Term Program for the Formation of a Territorial-Production Complex*; and on I.N. Voevoda, A.N. Teplov, and M.A. Sokov, *Optimum Use and Conservation of Forest Resources of the BITPC*.

abstraction, and it is only after the first two stages that reality can be defined. The conceptual model is a further abstraction and involves two major parts: a theory and a method, or a set of them, which can be construed as representing the *dynamics* of reality, and a set of data which can be construed as representing the *facts* of reality. This formulation is what is often called modeling, but it is only one stage, although more complex than is indicated by one box. It takes the form of technical reports and a directory of source data. (The latter may already require computerization.)

The formulation of the conceptual model has value in itself and in some cases the modeling effort may stop here. If computerization is to be used, however, then there are two more stages. The fourth may be called the *structural model*. It is a second conceptualization that is completely divorced from reality, even its abstract form. What is taken to be reality here are the methodology of the conceptual model, the source data defined for it, and the computer system that is to be used. The structural model takes the form of flow charts, data descriptions, computer resource requirements, programming language, operational specifications, etc. It is essentially a translation and elaboration of the conceptual model into a design of the fifth stage.

The fifth stage is the *operational model*, i.e., computerized, checked out, documented, etc. The creation of this stage is a construction process which may itself be very complicated and expensive. In reality, it is a set of computer programs, data files, and supporting documentation. However, to the formulator of the conceptual model and the technological experts whom he is serving, it appears to be a working version of the conceptual model, which in turn appears to represent reality.

The whole process is complicated and abstract. Furthermore, it involves skills and methods which are quite diverse. Methodologists often do not understand software. Technological experts often do not understand optimization algorithms or integrated data bases. And so on.

Let me now pose a few questions regarding the three previous papers, and point at the part of the above framework to which they apply. In Bandman's paper, several questions arise with respect to his Figure 2. Since the solutions to a number of models are shown as interdependent--and these dependencies cross stages--presumably iterative adjustments must be made. If so, how many grand iterations are required, how are these scheduled, and what is the experience with respect to convergence, or at least stabilizing to acceptable agreement? Indeed, it would appear that some sort of control model might be desirable to make effective use of the complex scheme shown in the Figure. Are consistency checks automated to any degree, or is human intervention used to make judgments about the results of various cases?

Let us look now at problems in computerization. If one considers numerous variations in the detailed coefficients of Bandman's Figure 5, and these models as well as others embedded in the elaborate system of models of Figure 2, it is evident that data management, model generation, and result summarization (reporting) must be at least as important as optimization algorithms. Even experienced users of computerized optimization techniques, to undertake such a program of calculations, might want a flexible and powerful data management system fully coordinated with optimization software. I would like to pose a specific question. Would cooperative efforts in research into such specialized application software be an area of interest.

In the paper presented by Kozlov, I have a question about the model defined by formulae (1)-(3). Since the indices k and t (products and time) do not appear in the functional $L(z)$, this implies that the required output of all products produced by a unit, and for all time periods, are locked together for each of the modes of use of the unit. In general, the solution to this model will involve a linear combination of modes for possibly each unit. Hence, this implicitly assumes that such combination modes are meaningful. There is the further implication that one mode will be used throughout the entire time span under study. If one can assume that it is possible to change modes from year to year, and further that there are no cumulative constraints on scarce resources, then one would have T models, one for each year. This would appear to allow more flexibility and make solutions easier to obtain.

With regard to the same model, straightforward ranging procedures can be used to determine the maximum change in each Q_k^t which will not change the optimal basis. Was any use made of such techniques, say for establishing stable ranges for the Q_k^t ?

Turning to the second half of Kozlov's paper the use and elaboration of network techniques for the model of economic program implementation is very interesting. Essentially, this is a variation of decomposition in the mathematical programming sense, but with an unusual turn in the roles of the master and subproblems. The master feeds *requirements* rather than *prices* to the sectorial submodels, and the subproblems return *prices* rather than flow *coefficients*. Also, the master is a network problem with time-dependent costs, and an intermediate computational stage is used to transform the prices returned by the submodels into more usable form.

As in all decomposition techniques, one is struck by the volume of required intermediate data and its identification. First, it would seem that in planning for the implementation of several territorial production complexes in the same time frame, the sectorial models cannot be used independently for each economic program implementation. There is bound to be competition for products of the various industries among the different

TPCs. For example, they would each seek to obtain products in the cheapest time periods within their other constraints.

A little arithmetic indicates that a possibly large amount of intermediate tables may be required. However, the paper seems to imply that in fact these tables (the f_{ij}) are not pre-computed but are calculated on demand by a subsidiary model. This would seem a reasonable approach, but further amplification would be appreciated.

The paper by Voevoda clearly indicates that an enormous effort is required for data collection and organization for projects of the scope discussed. One almost becomes weary in even reading about the variety of classifications that must be developed and the detailed facts that must be collected regarding the resources of a region. Yet without such information, it would be impossible to formulate and implement meaningful models, much less attempt any kind of formal optimization.

The models that have been formulated to represent the interrelationships within the region, and the exogenous demands, appear to be classical LP models of large size. The total matrix structure shown in Figure 2 in this paper is, of course, in standard block-angular decomposition structure which appears entirely suitable. Certain questions do come to mind, however.

First, possible sites for plants must be to some extent mutually exclusive and, perhaps to a lesser degree, also different possible modes of operation. To fully account for this, either a possibly large number of combinatorial cases must be solved, or zero-one variables must be used. Possibly, continuous variables might be good enough for a first approximation after which certain sites could be definitely eliminated and operational modes redefined. How were these considerations handled?

Second, it is not clear how forest reproduction measures can be represented, since these will depend on where and to what extent felling operations are carried out, which are themselves variables. Could this area be amplified?

Turning to computational aspects, is a large-scale decomposition algorithm actually used--one which is workable? If so, it would be very interesting to know what approach was taken, and what the experience has been regarding computational efficiency, etc.

A final question on this paper is: how are the enormous data management requirements, which seem to be implied, handled?

One last question on all the papers. What kind of computers and basic software were used for these models--that is, approximate size and speed of the hardware, and the programming languages and style of operating system? In particular, are interactive systems available and if so, are these valuable?

Discussion

Discussion focused on the application of models to regional development. The number of models required for the formation of a complex depends on the goals and tasks of the project and the user.

The models that have been discussed in the Conference presentations are primarily designed to aid the preplanning stage of a project. State planning bodies are the model users, as reflected in the level of the models. In some cases, national models have been developed. Efforts are being made to develop models that will be useful in the actual planning process.

The complexity of a model increases as the tasks become more complex. Many of the current models were designed to assist in the formation process of a complex. New models are now being designed to achieve the improved use of resources in an existing complex.

Through the centralized system of planning, models are interconnected at the higher levels. The upper levels determine the direction of the specialization of lower-level models. In the past, linear approximation models have been used; currently, a nonlinear model is being run for the Bratsk-Ilimsk Complex.

Shadow prices from mathematical programming models are considered auxiliary information to be passed on to the policy bodies, and are not used directly in the setting of prices. These variables are regarded as auxiliary magnitudes that are internal to the model, and their values at different stages of the iterative process may serve as rough estimates of the social costs associated with the execution of a given step of project construction.

At the close of the session the participants suggested that cooperation in this area between IIASA and modeling institutions in the Soviet Union should be pursued.

CLOSING SESSION

Closing Remarks

H. Knop

We have had many opportunities to express our thoughts about the Soviet presentations at this Conference, and it is therefore not necessary to repeat these now. Information has been exchanged, ideas have been suggested, and part of the objectives of the study of the BITPC has been fulfilled. Our task will be completed when we go to Bratsk and finalize our reports. As an organizer of this Conference, I want to express my satisfaction that our expectations have been fulfilled. We are pleased to have had the opportunity to meet such a large number of distinguished scientists and practitioners both from the USSR and elsewhere. Preparations for this Conference have been excellent, and I want to express our gratitude to the Soviet delegation led by Professors Aleksenko, Aganbegyan, and Milner, helped by the delegation from Siberia--Drs. Smirnov, Gukov, and Evenko; I also want to thank all who took part in the discussions.

There have been indicators of worldwide interest in this Conference: in addition to the recent press conference, the Austrian television reported on the Bratsk-Ilinsk program and on our Conference. At the invitation of the Czech National Member Organization, we will join the Soviet delegation in presenting in Bratislava a shorter version of this Conference; attending this conference will be specialists from Czechoslovakia and Poland concerned with the planning, management, and modeling of regional programs.

This Conference has shown the value both of East-West scientific cooperation in the field of socio-economic systems, and IIASA's work in applying systems analysis to regional development problems.

Finally, I would like to thank the Director of IIASA for chairing the plenary sessions, and the IIASA staff who helped in the preparation of this Conference--in particular, the members of the Management and Technology group.

G. Aleksenko

As this Conference draws to a close, we can look back and observe the results. It was interesting to hear the reports and comments of the participants from many countries. The participants have been acquainted with all aspects of the Soviet approach to constructing and organizing large-scale programs of regional development, on the scale of the BITPC. The papers

presented and the discussions that ensued enabled us to learn about the scientific methods used in developing the complex, its role in developing the productive forces of the Soviet Union, its production and organizational structure, the development process, and how this specific project illustrates certain features of our socialist system.

A foundation was built for further study of the Soviet experience by IIASA. Owing to the limited time we could report only on the main problems of the construction and functioning of the BITPC. There are a number of models and methods for solving problems of organization and economy that might be of practical and scientific interest both to the participants and IIASA. We look forward to explaining our experience in implementing large-scale programs to the IIASA delegation that will visit Bratsk and Moscow in June.

During the Conference a number of questions were raised that will stimulate more research on methods for planning and implementing regional programs. IIASA has played a major role in the exchange of scientific information among scientists from various countries. I would like to thank all the participants for their contribution. I would also like to thank Dr. Levien, Director of IIASA, and the IIASA staff for the opportunity to hold this Conference. I wish IIASA every success in this complex task of developing applied systems analysis for the benefit of all interested parties. On behalf of the Soviet delegation I would like to express our gratitude for the hospitality provided to us.

H. Mottek

This Conference has provided us with a number of new findings and suggestions for which I would like to thank our Soviet friends. The BITPC is characterized by its complexity, its long-term nature, and its vast management organization. The stepwise approach to building up production and the creation of the necessary infrastructure was of particular interest.

New ideas also arose in discussion on the system of planning, from the preplanning stage to long-range planning for 15 years ahead, and on the interaction of all the organs of management--particularly that between the Board of Directors and the local Soviets. The BITPC example has demonstrated the effective interplay of various scientific disciplines with practical implementation. We have also received an insight into the unity of modeling and planning.

The painstaking preparations made for the Conference provided the basis for its success. Our heartfelt thanks are due to the Soviet delegation and the IIASA team, but above all to the staff of the Large Organizations Project. The excellent information material on the BITPC has aroused our desire to see

this area ourselves. We wish the conference participants from Bratsk all the best for their future work on the further expansion of the Complex.

S. Komorovski

During the last three days we have tried to assimilate the knowledge and experience transmitted by our Soviet colleagues. This is a difficult task in the short time at our disposal: we have to digest the results of this Conference for a much longer time than we have spent here in the pleasant atmosphere of IIASA.

The BITPC, with its impressive size and the conditions in which it was realized, is an enormous achievement in physical and resource terms. When we systems people discuss it, we tend to lose sight of the dimensions of the problem, the physical conditions, and the hard work done there, and to concentrate on the complexity of the system. Our professional interest is in learning how that complexity was resolved, how implementation of such a large task was managed. We heard the subject discussed from very different angles. Roughly we may distinguish the technical and the economic approach; many others--managerial, planning, analytical, and so forth--can be developed, and all of them must be joined in a proper scheme. We also saw that there is a system with several subsystems, producing a complicated picture which needs the systems approach to be resolved at all.

It is difficult to make detailed conclusions about what we have learned at this Conference; but I would like to share certain general impressions with you. I was once again convinced that the sectorial and the regional approach are not in competition: they are merely two approaches to a system from different angles, for the purpose of dividing it into subsystems for public consideration. I think this is an important point in dealing with such systems.

Another impression is that what has been described here can be realized only under one given condition, that of management of the economy and society, which implies central planning. I insist that we must talk first of management and then of planning, and not the other way around, because then we would see a substitution of management by planning, which to my mind is a dangerous situation that might obscure the solutions of such integrated problems.

We must thank our Soviet colleagues for the enormous efforts they made to share with us their knowledge and experience, and IIASA for conceiving and organizing this Conference. When we have digested what we have heard here, we will be able to apply it to our practical everyday tasks.

E. Schulz

I took the floor not on behalf of a delegation from the FRG, since there is none here, but on my own behalf. What I will say is my personal opinion only.

I wanted to make a few remarks on the procedure of the Conference, because I am a generalist and do not understand very much about the substance of the Conference. Let me first express my gratitude to IIASA for taking the initiative to call such a Conference, for the hospitality shown to us, and for the excellent organization, and my high regard for the success of the organizers in bringing together outstanding personalities from so many countries--countries of different political systems and different scientific approaches.

Because of this diversity, one should not expect the scientific results of meetings like this to be comparable to the performance of a well trained soccer team. This kind of conference is just in an initial phase; East-West cooperation in scientific work is only beginning, and mutual understanding must grow over many years.

Let me put forward some suggestions from my own experience in organizing East-West conferences at our Institute. I would propose increasing the number of symposia of this kind as much as possible, but drastically reducing the number of participants in the different sessions. Secondly, I would propose limiting the number of presentations and allowing far more time for informal discussions. I hope that our IIASA host will take those suggestions as proof of my high esteem for the extremely useful work that is being done here.

In concluding, let me express my appreciation of the excellent presentation by my Soviet colleagues of the BITPC experience.

R. Tomlinson

This Conference, as far as IIASA is concerned, intersects two streams of interest. One is interregional planning, and the other is the organization of large projects, which is a IIASA project. Let us examine why this kind of project exists at IIASA.

I have learned in ten years of running a large operational research systems analysis team that one can build models about almost anything, but there are two real difficulties. The first is to build models whose output has meaning in view of the imperfections of the data used, and the uncertainty of the many relationships in the models. The second difficulty is to build models whose output is useful to decision makers. Many models have been built that remain within the empire of the model builders and never penetrate the decisionmaking process.

In an institute of *applied* systems analysis, there must be a team concerned with preparing useful models. Of course, sometimes models can not be used for organizational reasons, and one must look in a systems way at the organization. This is why IIASA's work is important, and in these discussions, we should consider both the retrospective and the active studies of inter-regional development. For most problems of applied systems analysis, there are known techniques that may be extended, developed, and applied to new situations. Unlike other projects at IIASA, the Large Organizations Group does not have a ready made technology to build on. IIASA has been most innovative in this area. One of the most difficult problems associated with this project at IIASA over the last 18 months has been to wait for these ideas to develop. During my visit here I have learned that this is now happening.

I was on the team that visited the Tennessee Valley Authority (TVA) and some of the things that we learned influenced the questions that have been asked with respect to Bratsk. First, the TVA study provided a common experience for all members of the team, from different countries, different backgrounds; when there was a problem they could go back to a common experience and talk about it in that context. This has been an essential feature within the Large Organizations Group.

Secondly it soon became clear that the organization of the TVA was a product of its own history, and we realized that Bratsk would be a similar case. The static picture is needed to understand what is happening, but it is not very important or even helpful to the research. We found that what we were trying to study was how people or individual groups assumed responsibilities within the organization, how they worked, the kind of pressures they experienced, how they responded to various kinds of controls, and how the organization as a whole responded to conditions that were not predicted when it was set up. We began to ask questions along these lines; they were not the questions that we had expected to ask when we started the investigation. They were questions that could be answered only by a detailed question-and-answer process, face-to-face across a desk; they could not be answered at a conference like this one. What resulted was the glimmerings of concepts by which we could build a structure for asking questions; moreover some theoretical models began to emerge. Naturally, this could not have happened if the TVA Conference had not taken place. But the real research took place when the team visited the TVA.

I will close by saying to our Soviet colleagues that we admire the great amount of work done in the preparation of this Conference.

M.I. Foster

I bring greetings to IIASA, and to the Conference participants, from those at the TVA who remember your hospitality from the Fall of 1974, and from a large number of people your visiting team got to know who recall your visit with pleasure.

My associate, Mr. Hinote, and I were looking forward to hearing our colleagues from the USSR tell us about their planning in the BITPC, and we have not been disappointed. We were very much interested in the planning processes, but even more in what has been done. This platform at IIASA is one of the few places where these two programs--the BITPC and the TVA--could have been discussed in the way they were. We have been asked some pertinent questions--why we did certain things in a certain way, what the results were, whether they could have been done in a better way--and it was good for us to have to think about the answers; I hope that our colleagues from Siberia will also gain from having such questions put to them.

We have also appreciated the comments and questions prepared by the IIASA staff, whose function, as I understand it, is to bring the latest technology in this field to bear on the subjects of the Conference. These questions probed, for example, whether we were using the latest and best techniques.

I have been asked here about similarities between the BITPC and the TVA, and in my judgment the differences are far greater than the similarities. But of course there are important similarities; I will mention just one of these, to let you know the seriousness with which the TVA views its role and that of the BITPC. Both of us are investing people's money. The people of our nations have worked and produced, and have not consumed all they produced; and what they saved they turned over to us to invest for the future. And that is really what we are both doing: investing this saving that the people have made us responsible for. I think that both of us will probably do a better job in the future because we have been asked to put on programs for our colleagues to look at and discuss. I wish our colleagues from the USSR continued success. It has been a fine experience for us from the TVA to see your program.

Y. Iwasa

This is the first time that I have participated in a conference dealing with a large-scale regional development program, having been unable to attend the previous IIASA Conference on the Tennessee Valley Authority. My interest in regional development programs is centered on compiling and fulfilling of objectives. The IIASA staff has shown that the application of systems analysis to such programs can do much to clarify not only how objectives are formed, but also the procedures and techniques needed to accomplish the initial goals.

The Soviet delegation has demonstrated that the methods of systems analysis, coupled with the support of previous experiences in development programs and with direction through the political, socio-economic and technological environment, can produce significant results in areas that are basically hostile and lacking in the supportive infrastructure.

These aspects of applied systems analysis, for clarifying the process of development, and the other for ensuring that development is ordered and proper, can do much to advance the use of a systems approach for other countries engaged in similar programs. I personally have much interest in both types of research. The technical sessions during the Conference focused on the more specific approaches used in different parts of the development process. Although the time allocated for the technical sessions and the discussions was short, I think the interactions between the Conference participants, the Soviet delegation, and the IIASA scientists produced fruitful and positive results. This Conference is an example of how international cooperation and the open exchange of ideas can enhance the field of regional planning and development.

I have been fortunate to personally visit the Bratsk-Ilimsk Complex in 1972 and 1975. This Conference has confirmed my impression that the Soviet delegation should be congratulated on the success of national economic planning as exemplified by the success of the Bratsk-Ilimsk complex.

In closing, I wish to extend my thanks to Professor Knop and the IIASA staff for the preparation of the Conference and its successful conduct.

R.E. Levien

One of the prerequisites of a good manager is vision, and we have just seen why Professor Gvishiani is a good manager, a good leader and a great chairman of the IIASA Council. His vision has guided us in the past and will continue to do so in the future.

We have had a successful, short and intense Conference. All of us have thanked the organizers, and I would like to add my thanks for the excellent work by Professor Knop and Academician Aganbegyan and his group. I would like to add the Institute's thanks to those who have participated actively in this Conference. A conference is only successful to the extent that there is two-way communication, and from what I have heard about the interaction during the working sessions and the breaks, I think this Conference has been very successful.

But the interaction that IIASA seeks is not only that at conferences. We are an international Institute with a very ambitious research program and about 70 scientists to carry it out.

If we were to limit our efforts to the work of these 70 scientists, we would never be able to make significant progress on the problems we want to address. The strategy that we choose to follow is to catalyze, inspire and link the work going on in other countries, and to develop collaborative associations with scientists and institutions so that our efforts can be amplified and we can help to amplify the efforts of others.

In that spirit I would like to invite you to become honorary IIASA alumni, with all the rights and obligations that this implies. A IIASA alumnus takes pride in having been associated with IIASA, but his responsibility is to continue this association; and I hope you will feel responsible to continue working with us on problems of regional development, management and systems analysis. For our part we will be happy to keep you informed of our work and to respond to the initiatives that you may wish to send to us. At both the individual and the institutional levels IIASA seeks to fulfill these collaborative linkages. When we leave Baden today, please return to your home institutions with a continuing interest in IIASA, and we will remain associated with you.

J. Gvishiani

When we first thought of creating an institution like IIASA, we wondered how we might shape this idea into a constructive form. I am pleased to have been able to attend this Conference, which to me is significant not only for the topics discussed, but also for the spirit in which we discussed them. I think this is what we regarded as the right way to develop our activities--to bring the scientific community together to solve problems that are of importance to the advancement of science and to mankind. Maybe this is an ambitious statement, and maybe our contribution is very modest; but what is important is that in our complex world we have made a positive contribution.

IIASA is approaching an important stage in its existence, one in which it can and should become a catalyst of ideas and methods in systems analysis. The transition to this new stage is evident in the area of organizational systems, characterized by two important IIASA conferences: one on the Tennessee Valley Authority in the US and the other on the Bratsk-Ilmsk Territorial Production Complex in the USSR.

I must admit that the Executive Committee, and both the former and the present Director of IIASA, were not sure that we had found the key problem for study by the Large Organizations Project. But, rather than speculate on a broad range of problems that might have been examined, I think it was an excellent idea to hold these two conferences. As a result of the second, we can now conclude that this is the best approach for IIASA. I endorse the view expressed here that through these conferences and their proceedings, IIASA can make an impact not only on its

own state-of-the-art research but also on the work being done in this field by institutes of the National Member Organizations and the scientific community worldwide.

What are the advantages of a regional approach from the systems analysis point of view? They result from the fact that a region is a complex of different factors and components--technological, economic, social, legal--that interact to create the regional system as a whole. This has been stressed in the plenary meetings and technical sessions. Industry, agriculture, distribution systems, services, environmental problems, education, health, and the like--all these are looked at as a whole, as an integrated system. Systems analysis is particularly applicable here, since there is a need for integrating science, experience, and human activities within a natural whole. In our retrospective analysis, we have perhaps been discovering that we have talked of this all our life and are now labelling it systems analysis.

What we are trying to do is to systematize a practice which was complicated, often lacking in details, and largely empirical. This will produce not an ideal model, but one incorporating the knowledge and expertise of the scientists and administrators who have dealt with these complex problems. The Conference vividly demonstrates that such models might be used in practice, not merely to assess theoretically what has happened, but rather to try to influence practice--always the main objective of any sound theory.

In these few days we have touched on some problems of real substance. We have the feeling that we now have more knowledge, and that we must combine our efforts in paving the way for applying the most efficient techniques and methods. We will need time to explore the findings of this Conference, and I am sure that your understanding of Bratsk-Ilimsk will be enriched when some of you find time to visit the Soviet Union.

Both the study of the TVA experience and that of the BITPC show the efficacy of international cooperation of scientists within the jointly created and fruitfully developing Institute. This is particularly important for the art of systems analysis and methodology, whose use is of growing interest all over the world for solving a broad range of regional, national, and global problems. The study of the TVA and the BITPC permitted us to see different models of complex approaches to rational use of resources, regional development of productive forces, coordination of different branches and levels of economy and its organization and management.

The task is not simply to compare two different models. The behavior of a model is determined by the social and economic environment; and the region, as a subsystem of the entire socio-economic system, inevitably causes certain differences in models, in methods of organizing and managing. But in the implementation of scientific methods of organization and management, there are

common features that reflect objective trends toward optimizing resource use and organizing rational development. Thus each of us may find in another's experience something that can be applied to his own conditions.

These differences are not only socio-economic--because the environment and the rules of the game differ--but also due to differences in regions and tasks, in objectives; we are not so naive as to think that we can work out a model that is applicable to all cases and in all circumstances. But the process of enriching our knowledge, trying step by step to deepen our understanding, giving scientific tools to practitioners--this is a noble task. That is why we examine complex cases: to see what has actually happened and what has not yet been resolved. Any economy, any region can be differently organized: one might have a more centrally organized management system, the other a less centralized or decentralized one. But from the systems analytic point of view it is always organized, and we try to understand the peculiarities of each system and then to determine what practitioners should do in specific conditions.

What can IIASA do in this direction? The problem is so vast and so important, and there are so many scholars in the National Member Organizations and elsewhere, that the Institute's catalyst function is particularly important. I think we must focus our attention now on the results of conferences such as this one and make them known to a much broader audience. We should not only publish proceedings and reports of what we have done so far, but prepare condensed versions for wider publication.

In coordinating our efforts, time will be needed to derive lessons from the knowledge now at our disposal, and we will need to exchange information. I think that IIASA will help to establish contacts among institutions that are doing studies of this kind and will act as a clearinghouse. The Director of the Institute, the Executive Committee, and the Council are all considering what might be the next step: how we can broaden our ties. After three years of existence, we have a nucleus of scientists, we can extend our links; and it is crucially important to find the right policies for interacting with research institutions, first of the NMOs and then of international organizations. There is a growing interest by many organizations, among them the United Nations specialized agencies, in contacts with us; ahead of us is the World Conference on Science and Technology; and there are various initiatives to improve the contacts among institutions dealing with problems of management. Our feeling in the Council of the Institute is that wherever possible, when it does not conflict with the interests and development of the Institute, we should focus our attention not only on a limited number of research programs, but also on our role of catalyst.

As to the future, it is important that we consider not only retrospective cases, but also practical activities in the widest sense. We might, for example, act as an international team

assessing what is to be done. Keeping this direct liaison with all of you, and with many others who follow the activities of IIASA, may give us the knowledge and skill that are needed to make recommendations.

It is my view that IIASA, as a unique international organization, has progressed very well. I am confident that in the future the Institute will be even more active in fostering better cooperation among scientists, and that, as the problems mankind faces become more significant, we will become better able to tackle them. This is an honorable task, and our aspirations and hopes are not based only on a strictly businesslike approach; the decisive thing is the spirit of the Institute, the spirit in which we work. We are oriented toward obtaining results, and we will progress better if a businesslike approach is combined with a growing sense of social responsibility; a sense that there are problems that are multidisciplinary, that are international, that have to be tackled in the manner most appropriate today.

I am of course far from trying to evaluate the scientific significance of what has been done here; but I would like to say that everyone I have talked to rates the Conference very high. I want to join those speakers that complimented the organizers; I think this is the way in which the Institute should progress.

APPENDIXES

Appendix 1

Information on Economic Planning And Management Systems in the USSR

(Source: Institute of Economics and Industrial Engineering, USSR)

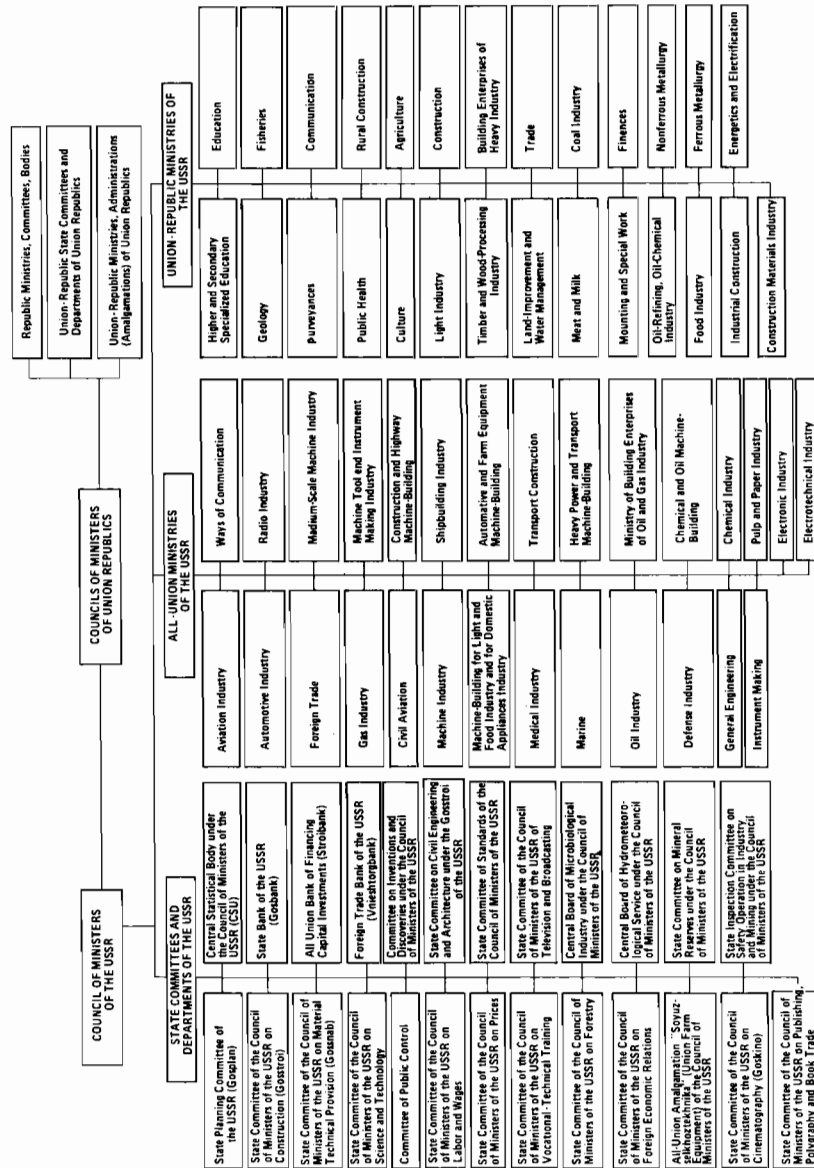


Figure A1. Management of the national economy in the USSR.

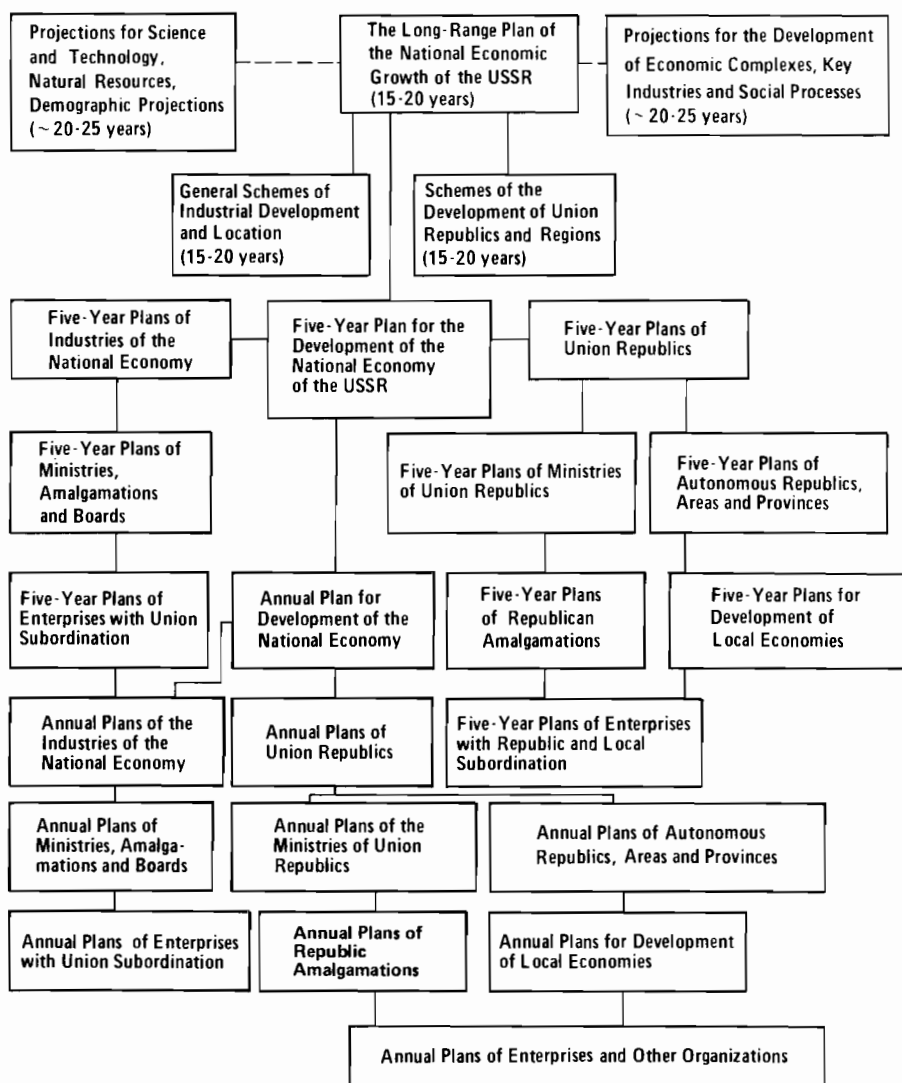


Figure A2. System of national economic plans of the USSR.

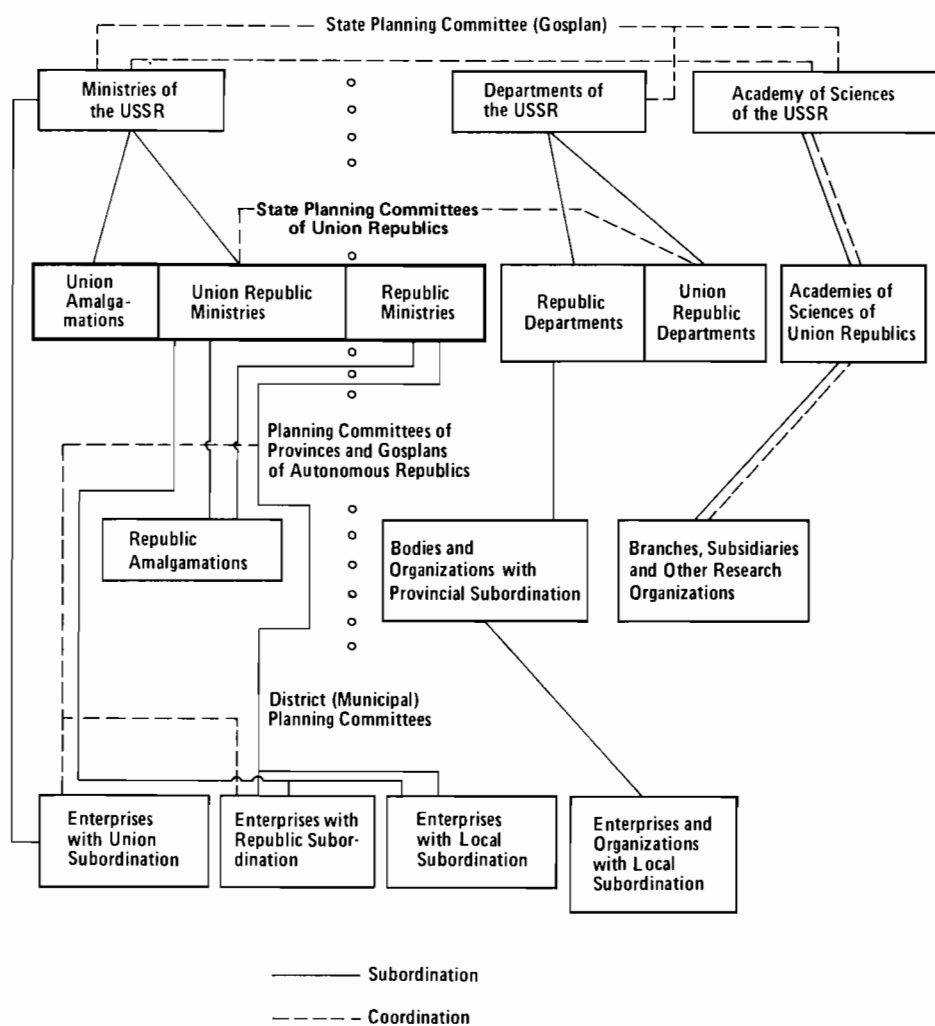


Figure A3. Planning bodies of the USSR national economy.

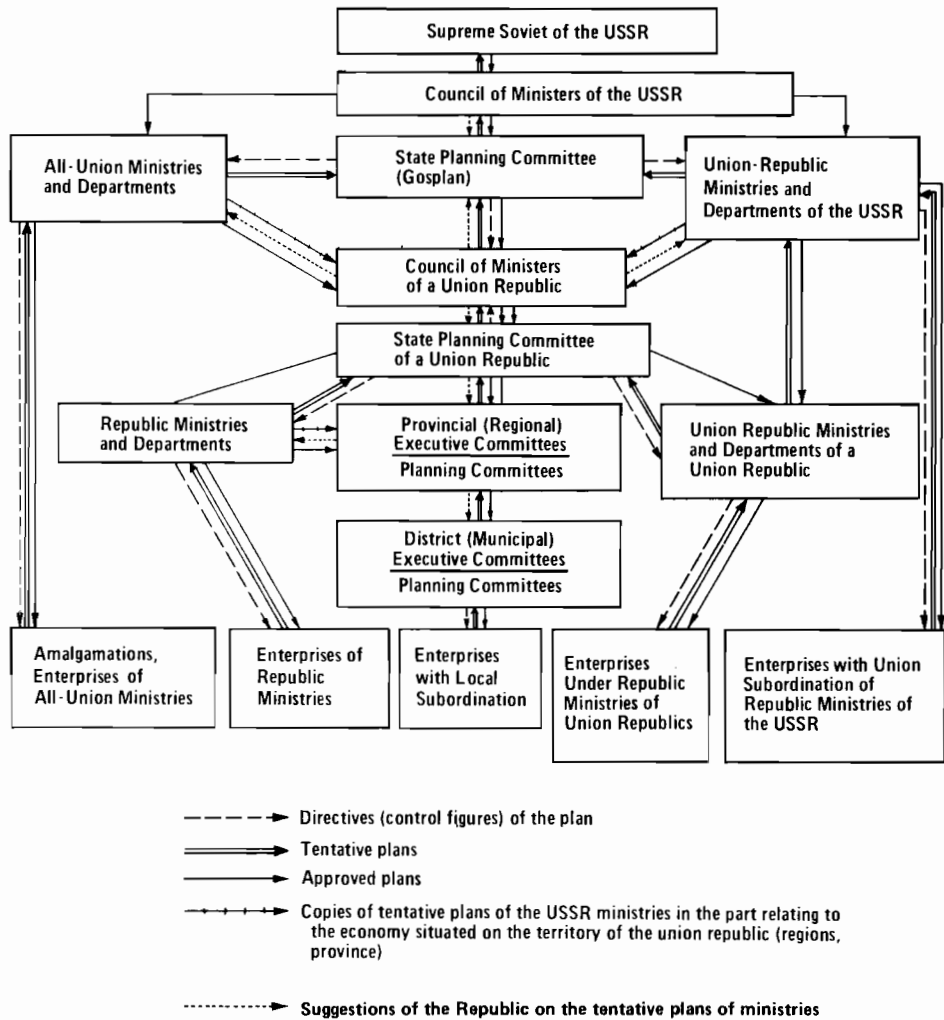


Figure A4. Evolution of the USSR national economy growth plan.

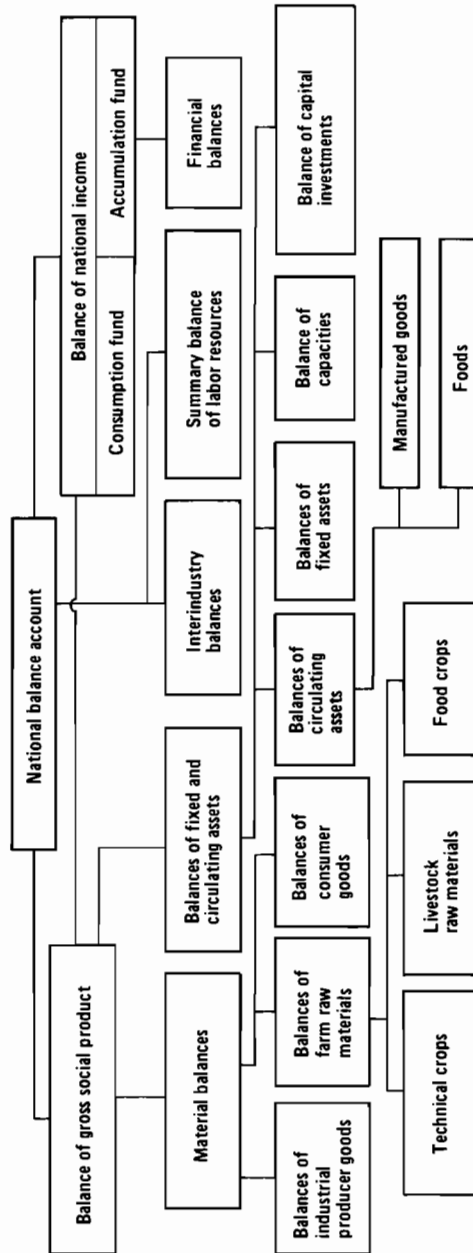


Figure A5. System of balances in the development of national economic plans of the USSR.

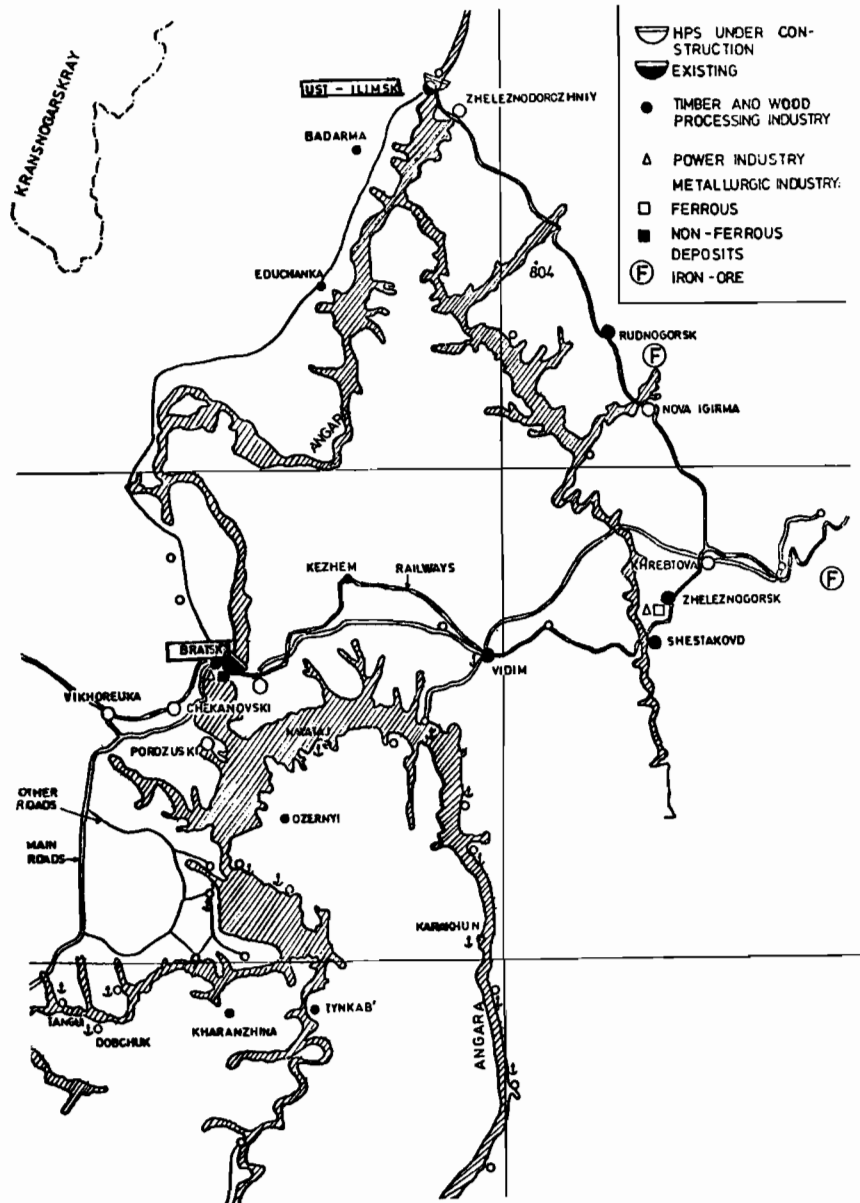


Figure A6. Map of the BITPC as of 1975.

Appendix 2

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